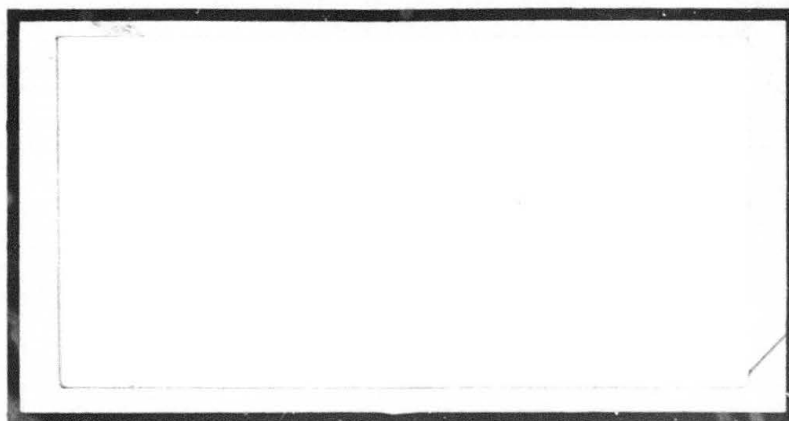DDC

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UNITED STATES AIR FORCE
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SIMULATION AND ANALYSIS
OF AUTODIN II
NETWORK DESIGN

THESIS

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GCS-80D

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(6) SIMULATION AND ANALYSIS OF AUTODIN II

NETWORK DESIGN.

(9) Master's thesis,

by

(10) James W. Healy
Denzel H. Henderson

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Thesis

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Ohio

Preface

The need for a comprehensive computer communication network has been evolving over the past years due to the increase in the number of information systems in the Department of Defense (DOD). There is also economical considerations of establishing a single large reliable and comprehensive communications network as opposed to numerous small to medium communications networks.

The AUTODIN II computer communication network is designed to meet these needs. However, communications requirements change and, as with any large project during design and development phases, questions are raised as to the operational capabilities of the system. Many such questions may be answered through simulating the network in its operational environment. This thesis effort developed a computer simulation program of the proposed AUTODIN II network (or any variations of it) in an environment that can be changed either permanently or dynamically.

We had hoped to have operational data from an initial three node AUTODIN II network to validate the simulation, but the data was not available before this thesis effort was completed. Also, we were desirous to test hypothesis concerning other AUTODIN II configurations and ascertain the "weakest links", if any, of the present proposed network, but sufficient time was not available. Others are invited to carry out these tasks.

We would like to express our thanks to two AFIT faculty members, Dr. Thomas Hartrum and Maj. Alan Ross, for their interest, encouragement and friendship during this thesis effort. Our loving appreciation is expressed to our wives and families whose love and understanding endured through this graduate program.

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Abstract

The AUTODIN II computer communications network is expected to provide for present and future Department of Defense communications requirements. The AUTODIN II requirements approach for development is to start small, meet the known validated requirements, and grow as requirements increase and the needs for service change. The background and present and future development of AUTODIN II network is discussed.
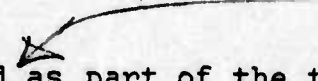
The proposed AUTODIN II network configuration is designed to provide reliable communications and minimal time delay for both interactive and timesharing and transaction-oriented systems. As development towards an operational network proceeds, questions concerning efficiency and optimality of the network are asked by both the design managers and future AUTODIN II users. To answer these questions, and other future questions concerning the operational AUTODIN II network, a simulation program at the switch control module (SCM) hierarchal level was developed. It

The simulation program allows the user to:

(1) Change the configuration network connectivity and add or delete nodes, SCMs, links and lines;

(2) Generate various communication traffic levels from any source location and to any destination location;

(3) Define network parameters, such as priorities, percentages of packet sizes, transmission times and special workload identification. and → (contour p XI

(4) Perform any of the previous options dynamically
     to analyze the effects of network configuration
     failures or catastrophic events.

A User's Manual is provided as part of the thesis
and may be used as a separate document. It describes the
input requirements and user options, the output data files
and their format, and a data analysis methodology.

Analyses are performed for two Air Force organizations,
each with opposite views or concerns regarding the AUTODIN II
network; one from the design managers view of the overall
network performance measures and specifications, the other
from the user's view of the specific netowrk performance
measures for a particular type of workload and priority.

CHAPTER 1

INTRODUCTION

Background

In recent years the number of computer information systems with geographically dispersed terminals has experienced continuous growth. These information systems are transaction oriented and require online communications for interactive timesharing, remote job entry and bulk data transfer. Each information system's transaction application has usually required the establishment of its own dedicated communications network with special leased lines.

In 1972, the assistant Secretary of Defense for Communications, Command, Control and Intelligence tasked Defense Communications Agency (DCA) to make recommendations for a common Defense Communication System (DCS) to fulfill computer communications requirements for the Department of Defense (DOD). DCA was also tasked to prepare a plan to fulfill the communications requirements for the World Wide Military Command and Control System (WWMCCS).

DCA had already initiated a comprehensive study to determine the present and future data communications requirements in the military environment. From this study projections into the mid-1980's indicated that within DOD there would be approximately 2500 computers involved with data communications with 20,000 input/output terminals. The study recommended an AUTODIN II plan to be written which called for 47 worldwide data communication switches. This recommendation was later revised, and the current philosophy is to start small, meet the known validated requirements, and then grow and evolve as requirements and the needs of the DOD community increase or change. In the technology area, the DCA study concluded that packet switching would be the best approach to use in AUTODIN II. The AUTODIN II Request for Proposal was released in 1975 and the contract for development and implementation was awarded to Western Union Telegraph Company in 1976 (Ref 1).

AUTODIN II has similar capabilities and performance characteristics to the ARPANET developed by the Defense Research Projects Agency. Subscriber computers and terminals are connected to the nearest AUTODIN II packet switching node (PSN). At the initial PSN, a subscriber message is converted to one or more AUTODIN II standardized messages or packets containing the destination address, security, precedence, community of interest information and other pertinent information. Each packet is dynami-

cally routed along one of several paths to the destination PSN, where the packet is forwarded to the appropriate destination computer or terminal. The delay time between message entry and delivery is so small, that each subscriber's computer or terminal will appear as a dedicated connection.

The path for a packet to take between the source and destination node is determined by a routing algorithm developed initially by Systems Control Incorporation (Ref 2). The algorithm is based on the ARPANET routing methodology but with major changes to implement the requirements of AUTODIN II. Like ARPANET, a distributed routing algorithm, as opposed to a centralized algorithm, was selected to increase survivability of the network. The routing algorithm for AUTODIN II provides more network information to each node in order to make nodes more responsive to network changes and to prevent looping of packets. The routing algorithm is of primary importance in the consideration of the AUTODIN II network configuration and a significant portion of this thesis effort.

A significant difference exists between the AUTODIN II network and previous computer networks. Previous computer networks have been constructed around a single computer per switching node. The AUTODIN II Packet Switching Node consists of one or more computers, called Switching Control Modules (SCM). Each SCM can act independently or with other SCMs. This concept allows expansion of a PSN (by adding SCMs) to meet permanent expansion of traffic workload.

Statement of the Problem

The DCA has not developed a satisfactory inhouse analysis of the AUTODIN II network to test and verify the proposed configuration and software. Systems Control, Inc. (SCI) simulated the PSN level of the network in developing the routing algorithm (Ref 2:App C). Rockwell International Co. (RIC) developed a simulation of a single PSN with one, two and three processors (Ref 3). Capt. J. Whittenton developed a simulation of the PSN level with the proposed network configuration (Ref 4). However, the AUTODIN II algorithm must be simulated for various network configuration and tested under potential stress conditions, including projected workload changes, network failures and various traffic levels and peaks. Knowing the results of the stress conditions for various network configurations will allow for corrective action to be taken before the complete network is developed. Thus, a significant dollar savings could be realized.

Scope

The primary objectives of this thesis are:

1. To model the AUTODIN II backbone network, that is, from the time a message enters a PSN to the time it leaves a PSN.

2. To analyse the network behavior under projected operational and stress conditions.

Objective (1) will allow the user to simulate AUTODIN II,

varying numerous parameters, such as traffic levels, traffic fluctations, flow densities, workload systems and levels of priorities. For each set of parameters the user will be able to change the proposed network configuration to test another configuration. Verification of the model is through comparison with Capt. J. Whittenton's thesis results (Ref 4). The desired result of the simulation is to provide future users with sufficient flexibility to analyze the effects of changing network configurations and workloads.

The authors separately evaluated potential network problems from two opposing views: the designer and the customer. The evaluations were accomplished using the simulation model and the data available at the present time. The authors hoped to use actual data from the initial 3-node network scheduled for operation in June, 1980, but the schedules were slipped past this thesis effort.

The efforts to simulate all details of the AUTODIN II network are beyond the scope of this thesis effort. Therefore, only the backbone of the network is simulated; that is, subscriber computers, terminals and associated access components are not included in the model. The routing algorithm code was classified at the time of this thesis effort and was not available to the authors. Therefore, some differences may exist in the simulated algorithm and the actual algorithm. However, after discussions with DCA personnel, these differences should be very minor.

Approach

This thesis study was initiated through the interests of two sponsors, Capt. W. Nielson, DCA Engineering Center, and Major B. Gilbert, of AF/LEXY. Two AFIT students, the authors of this thesis, Mr. J. Healey and Mr. D. Henderson, were assigned respectively to these sponsors. Since each student required a model of the AUTODIN II network, a joint effort was established to produce a simulation program.

Early in the thesis effort, it was decided not only to attempt to produce a simulation model which could be used to satisfy the requirements of the sponsors, but also the requirements of other Air Force and contractor personnel who may be interested in analyzing the effects resulting from changes in the AUTODIN II network workload and/or configuration. A users manual of the simulation model was written for this purpose and is included as part of the thesis.

The first step in the thesis project was to research and study literature written on the AUTODIN II network. With a background into the present state of the art of the network and with the guidance of the AFIT faculty, the QGERT model was selected. Before selection of QGERT, a simplified version of the AUTODIN II configuration and routing algorithm was tested. Upon satisfactory results from this test, the authors proceeded to model the AUTODIN II network.

This simulation model differs from previous simulations in overall concept and fills a gap left by them. The Rock-

well International Co. simulation concentrated on simulating
the interactions occurring within a single PSN and the sim-
ulations by Capt. J. Whittenton and by Systems Control,
Inc., concentrated on interactions between PSNs within the
complete network. This simulation was developed to portray
interactions between SCMs within the complete network and
to allow SCMs to be added or removed from a PSN.

Upon successful completion of the model, the authors
simulated the proposed network and evaluated the potential
problems provided by their respective sponsors.

Sequence of Presentation

This report contains eight chapters. Chapter Two
describes the AUTODIN II network topology and architecture.
Included in this description are some of the requirements
and specifications of the AUTODIN II system. Chapter Three
describes the AUTODIN II routing algorithm, it's functions
and it's six modules. Chapter Four describes the simulation
model of the AUTODIN II network and routing algorithm. Also
included is the simulation input data in detail for future
users of the model. Chapter Five contains the author's
methods of analyzing the simulation model results. Chap-
ter Six describes the results of verification of the model
with Capt. J. Whittenton's simulation results. Chapters
Seven and Eight discuss the results of the simulation model
from two viewpoints: Chapter Seven contains the results of

the analysis by Mr. D. Henderson for Major B. Gilbert,
AF/LEXY and Chapter Eight contains the results of the
analysis by Mr. J. Healey for his sponsor, Capt. J. Nielson,
DCA Engineering Center. Appendix 1 contains the User's
manual for the AUTODIN II simulation model.

CHAPTER 2

THE AUTODIN II NETWORK

Autodin II Description

AUTODIN II is designed to provide economical and reliable data communications service for both interactive time-sharing and transaction-oriented systems requiring rapid response between terminals and computer-to-computer data transfers requiring high transmission capacity (Ref 1 : ES-2).

Subscriber terminals and computers (hosts) will be connected to the nearest PSN. Subscriber terminals are character oriented input/batch devices such as teletypewriters, CRT terminals and remote batch terminals and minicomputers that serve as communication handlers (Ref 5 :v-1-55). Subscriber hosts are larger computers capable of producing large quantities of data. The subscriber data (or messages) are separated into discrete elements called packets, each packet containing the address of its destination, security, precedence and community of interest information (Ref 1:ES-3). Community of interest information specifies which users are allowed access to certain information or messages. Packets will be dynamically routed to their destination

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along one of several paths. Each packet is routed independently so that if the subscriber's data requires more than one packet, each packet may take a separate route. The appropriate route is determined by the AUTODIN II routing algorithm discussed in Chapter Three. A subscriber computer will be capable of maintaining multiple virtual connections with other terminals or computers.

There are currently 47 ADP systems identified as potential candidates to connect to AUTODIN II network. These 47 ADP systems consist of 161 host computers and 1324 connected terminals (Ref 1:1). A number of these connected terminals are concentrator devices that, as a total, connect an additional 1700 devices to the AUTODIN II network.

The primary requirements and specifications for implementing the AUTODIN II network are (Ref 1:8):

1. Initial network configuration of four nodes, network control center and system test facility with capacity for termination of 200 access lines.

2. Capability to grow modularly to eight or more nodes with approximately 1700 subscribers.

3. Node capacities:

   1. 150 to 200 full duplex line terminations;

   2. Each line can be 110 bps to 56 kbps for subscribers and 9.6 KBPS to 230 KBPS for trunks;

   3. Throughput from 500 KBPS to 2.5 MBPS.

4. Maximum packet length of approximately 5300 bits.

5. Four traffic acceptance categories (CATI, CATII,

CATIII and CATIV).

6. Nonblocking for the highest precedence traffic.

7. Availability of 99 percent for single-homed subscribers and 99.95 percent for dual-homed subscribers.

8. Minimum impact on existing subscriber equipment/system software.

9. End-to-end undetected bit error rate of less than 1×10^{-12}.

10. Segment misdelivery rate of less than 1×10^{-11}. A subscriber's data is broken into elements (at the CCU for hosts, at the PSN for terminals) called segments. At the initial PSN, segments are converted to packets.

11. 300 MS maximum backbone delay for interactive and highest precedence packets (600 bit packets).

12. Transparent to text

13. Capable of supporting effective transmission rate of at least 75 percent of lowest access line speed on a connection.

14. Top-down, structured design of software using a high order language to its maximum extent.

15. Capable of being certified to handle all levels of classified traffic.

The initial AUTODIN II network will consist of three PSNs located at Fort Dietrick, Frederick, Md.; Tinker AFB, Oklahoma City, Okla.; and McClellan AFB, Sacramento, Cal. After thorough testing, a fourth PSN at Gentile AFS, Dayton, Ohio, will be added. The network will continue to grow to eight PSNs. As requirements increase, additional PSNs may be added to the network. The eight PSNs will be located at the present AUTODIN I CONUS sites. This was recommended

to keep overall costs down.

AUTODIN II Architecture

The AUTODIN II network and routing algorithm are the
results of studies performed by DCA, Western Union Telegraph
Company (primary contractor), Ford Aerospace and Communica-
tions Corporation and Systems Control, Inc. Each packet
switching node will be directly connected to at least three
other PSNs with backbone trunks (lines) between the PSNs
operating at a maximum of 56k BPS as shown in Figure 1. All
network elements will consist of common equipment, the
Digital Equipment Corporation (DEC) PDP-11 family of com-
puters. This will reduce quantities of spare parts and
simplify training.

The basic elements of a PSN are: Switch Control Module
(SCM), Terminal Access Controller (TAC), Line Control Module
(LCM) and Patch and Test Facility (PTF). (Ref 1:ES-21)
The SCM manages the basic packet switching function and inter-
facing of subscriber hosts and consists of one PDP-11 pro-
cessor. Each PSN contains one or more SCMs depending on the
quantity of throughput required. The TAC performs the func-
tion of interfacing the subscriber terminals to the network
and also consists of one or more PDP 11-70 processors de-
pending on the quantity of subscribers and the traffic
volume. The LCM, attached to both the SCM and TAC units,
terminates access lines. The PTF monitors and updates test
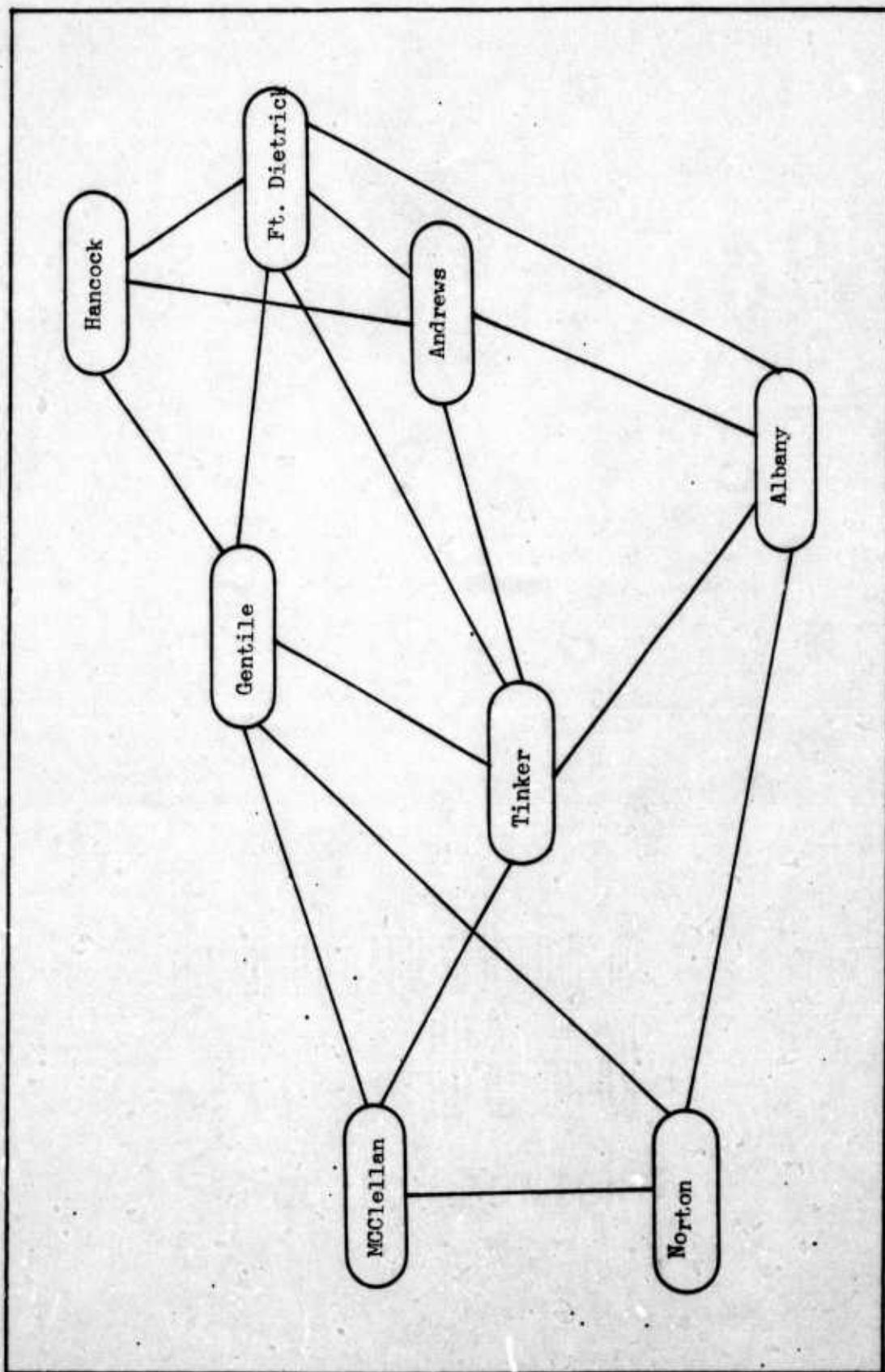
Fig 1. The AUTODIN II Network Connectivity

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points to restore or maintain circuit operations. The PTF uses the present AUTODIN I equipment. Each PSN also maintains a standby subsystem (PDP 11-70) to take over in the event one of the processors fails.

One of the design objectives of AUTODIN II was to minimize the subscriber hardware and software modifications when connecting a host to the network. This objective is met through the use of one of two channel control units (CCUs) as shown in Figure 2. The single CCU (SCCU) provides one physical port between the host and the SCCU and one logical connection to the network. The multiple CCU (MCCU) provides up to 32 ports between the hosts and the MCCU and 32 simultaneous logical connections to the network.

Located outside the eight PSN network will be the Network Control Center (NCC). The NCC gathers information on network performance and usage to respond to the management and control requirements of AUTODIN II. The PSN, SCMS, Links and trunks of the proposed AUTODIN II network configuration are shown in Figure 3.
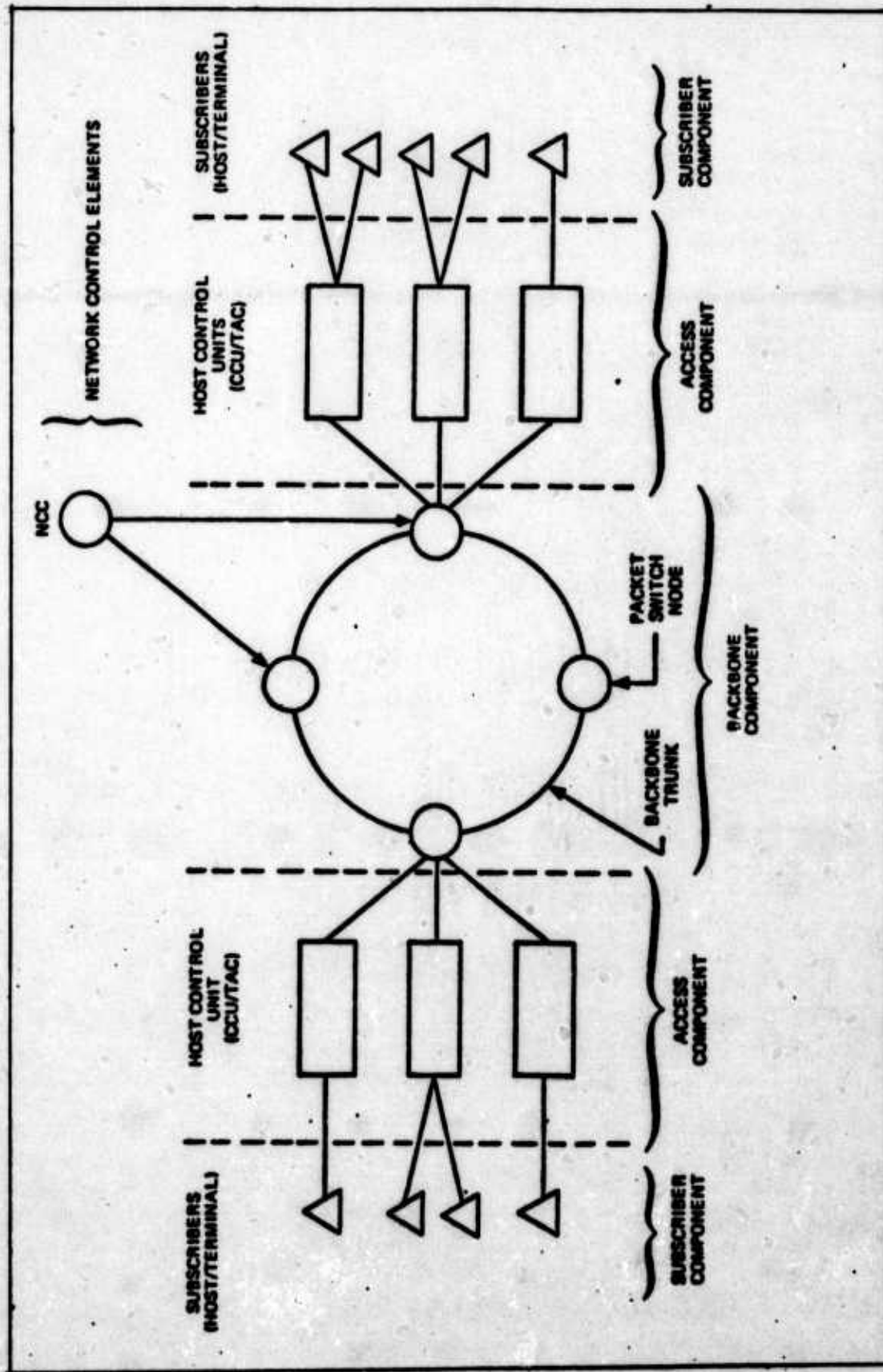
Fig 2. AUTODIN II Control

(Ref 2:ES.2-2)

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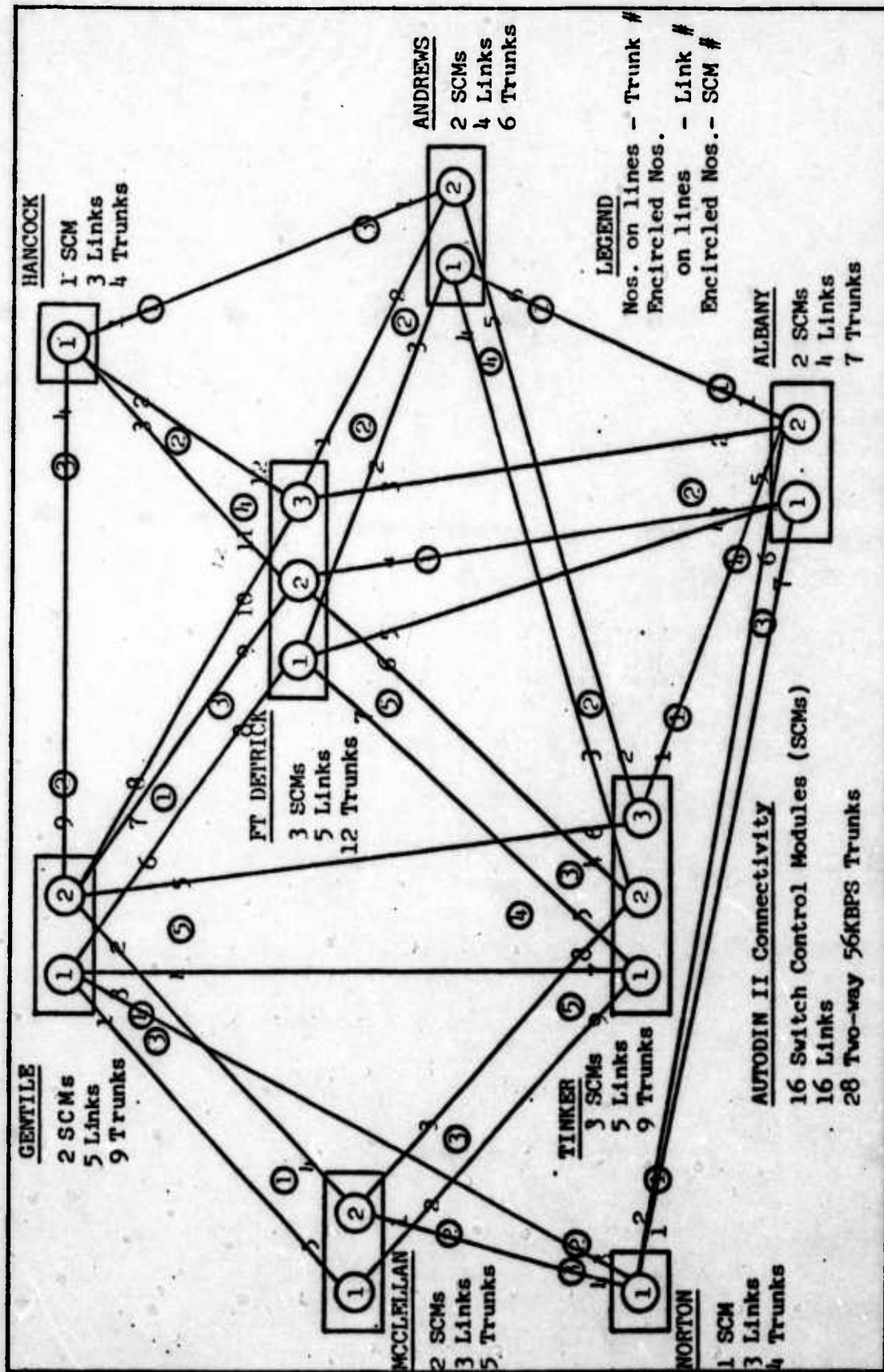
Fig 3. Network Layout of AUTODIN II

CHAPTER 3

THE AUTODIN II ROUTING ALGORITHM

Description

The AUTODIN II network employs a distributed adaptive routing algorithm. It is distributed in that decisions of the paths that packets will take are not controlled by a centrally located processor. It is adaptive because, for example, a system failure or link congestion in one area of the network will effect the decision as to what path packets will take in another part of the network. Adaptive routing is possible through the exchange of information between nodes in the network. The AUTODIN II routing algorithm is a derivative of the ARPANET routing algorithm with significant changes and improvements for application to the AUTODIN II network architecture and topology. In fact, a detailed study of the ARPANET applications and problems was made before the present AUTODIN II routing algorithm was proposed and accepted (Ref 5:V-1-105).

A routing decision is made by accessing routing tables maintained at every SCM. The routing tables contain the most current information on the network status. Thus a com-

plete path from a source SCM to a destination SCM is not determined by the source SCM; each packet is directed along the path the current SCM thinks is best. The operation of the AUTODIN II routing algorithm is summarized as follows

1. Each node maintains a copy of the network topology.

2. Each node monitors its output trunk group queue, and compares them with a predetermined congestion threshold value.

3. Whenever the connectivity of a node alters, or the congestion status of any of its trunk groups alters, or on a periodical basis, the node transmits a connectivity/congestion message to all other nodes.

4. On receipt of a connectivity/congestion message, each node updates its local copy of the network topology and updates its table of minimum-hop paths to all destinations. (Minimum-hop is the least number of hops required for a packet to take to reach its destination PSN from its present PSN.)

5. Tandem nodes (nodes between the source and destinations nodes) route packets by choosing only among the minimum-hop paths.

6. Source nodes route packets by choosing only among the minimum-hop paths and the minimum-hop + 1 paths.

7. When a tandem node or source node has two or more paths to a destination, it chooses a specific output link by minimizing the conbination of local queue delays plus bias representing the delay due to and reported congestion on the paths.

As discussed previously, each node contains one to three SCMs depending on the projected traffic volume at that node. Nodes are interconnected by from one to three logical

links with each link consisting of from one to three physical transmission lines (trunks). Each SCM processor operates with a copy of the routing algorithm and is therefore responsible for routing packets on the paths to the next PSN (SCM). A distributed routing algorithm may have problems with looping of packets between PSNs or SCMs or delayed information on network status. Looping is possible since each PSN, independently, makes its own decisions, and two PSNs could loop a packet between each other. Therefore, certain precautions have been built into the routing algorithm. Some of these precautions are

1. A field in the packet header is decremented and tested at each PSN to identify packets previously processed by the PSN.

2. No packets are returned to the node from which they have just been received.

3. All routing updates take place concurrently throughout the network and the full delay table is accumulated before the minimum delay route is chosen.

4. The exchange of routing information is planned to occur frequently enough (of the order of 0.5 seconds) so that changes are rapidly transmitted throughout the network.

It is important to note that although each SCM could appear to be considered as an independent PSN, this is actually not the case. A hierarchical approach is taken. The routing algorithm is implemented on an inter-PSN basis with a separate process for intra-node routing between SCMs. For example, if an SCM computes a path for a packet which

requires transmission on the line of another SCM within the same node, the packet is placed in the output queue of that SCM through the processor communications link (PCL). If the link contains more than one line to the next node the line with the minimum output queue is selected.

Design

An explanation of the routing algorithm tables, arrays and modules will now be presented. The routing algorithm data base is a table of the status of the network called the link distance (LD) table. The LD table is maintained by periodic internodal status packets. The LD table is a three state value defined from node i to node j;

$$LD(i,j) = \begin{cases} 1.00 & \text{if i and j are connected, but not congested.} \\ 1.01 & \text{if i and j are connected and congested.} \\ & \text{if i and j are not connected or } i = j. \end{cases}$$

An example of the LD table for the Andrews node is given in Figure 4.

If the LD table in a node is changed, an algorithm called MINHOP (to be explained later) is executed to generate, from the LD table, a routing distance (D) table. The D table for node N contains the distance to every other node in the network over each link from node N. The D table contains, for each link of node N, the distance, in number of hops, to each of the other nodes in the network. Only minimum hop

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DESTINATION NODE (j)

SOURCE NODE (i)	1 ALBANY	2 ANDREWS	3 FT.DETRICK	4 GENTILE	5 HANCOCK	6 MCCLELLAN	7 NORTON	8 TINKER
1 ALBANY	1000	1	1	1000	1000	1000	1	1
2 ANDREWS	1	1000	1	1000	1	1000	1000	1
3 FT.DETRICK	1	1	1000	1	1	1000	1000	1
4 GENTILE	1000	1000	1	1000	1	1	1	1
5 HANCOCK	1000	1	1	1	1000	1000	1000	1000
6 MCCLELLAN	1	1000	1000	1	1000	1000	1	1
7 NORTON	1	1000	1000	1	1000	1	1000	1000
8 TINKER	1	1	1	1	1000	1	1000	1000

Fig 4. Initial LD Table for the Andrews Node

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and minimum-hop plus 1 paths have non-infinite entries.
With the minimum hop and minimum-hop plus 1 constraint it
can be proven that looping cannot occur in the network
(Ref 2:A-2). An example of the D table for the Andrews
node is given in Figure 5.

The routing algorithm is made up of 6 modules: PAKROUTE,
MINHOP, RTABLE, TTABLE, UPDATE and MESGEN. The overall
organization of the routing modules is shown in Figure 6.
The UPDATE box includes both RTABLE and TTABLE modules. The
purpose of the authentication block is to ensure that only
actual nodes (not users) can send authentic network status
packets. Otherwise a user, either maliciously or accidentally,
could bring down the network by bringing all links down.

The reader should note from Figure 6, that the routing
modules are divided into two functions: Background functions
and Per Packet functions. An explanation of each of these
functions and each of the routing modules follows. For a
more detailed explanation, consult the references in the
bibliography.

Background Functions

Background functions are accomplished on a periodic
basis to update (if necessary) the routing tables and other
associated information as shown in Figure 7. The routing
of packets in the network is hierarchical in that first,
node to node routing is determined and second, which trunk

$D(i, \ell)$

NODE(i)	i	OUTPUT LINK (ℓ)			
		1	2	3	4
ALBANY	1	1	1000	1000	1000
ANDREWS	2	0	0	0	0
FT. DETRICK	3	1000	1	1000	1000
GENTILE	4	1000	1000	1000	1000
HANCOCK	5	1000	1000	1	1000
MCCLELLAN	6	1000	1000	1000	1000
NORTON	7	1000	1000	1000	1000
TINKER	8	1000	1000	1000	1

INTIAL D TABLE

$D(i, \ell)$

NODE(i)	i	OUTPUT LINK (ℓ)			
		1	2	3	4
ALBANY	1	1	2	1000	2
ANDREWS	2	0	0	0	0
FT. DETRICK	3	2	1	2	2
GENTILE	4	3	2	2	2
HANCOCK	5	1000	2	1	1000
MCCLELLAN	6	3	3	3	2
NORTON	7	2	3	3	3
TINKER	8	2	2	1000	1

REVISED D TABLE

Fig 5.   D Tables for Andrews
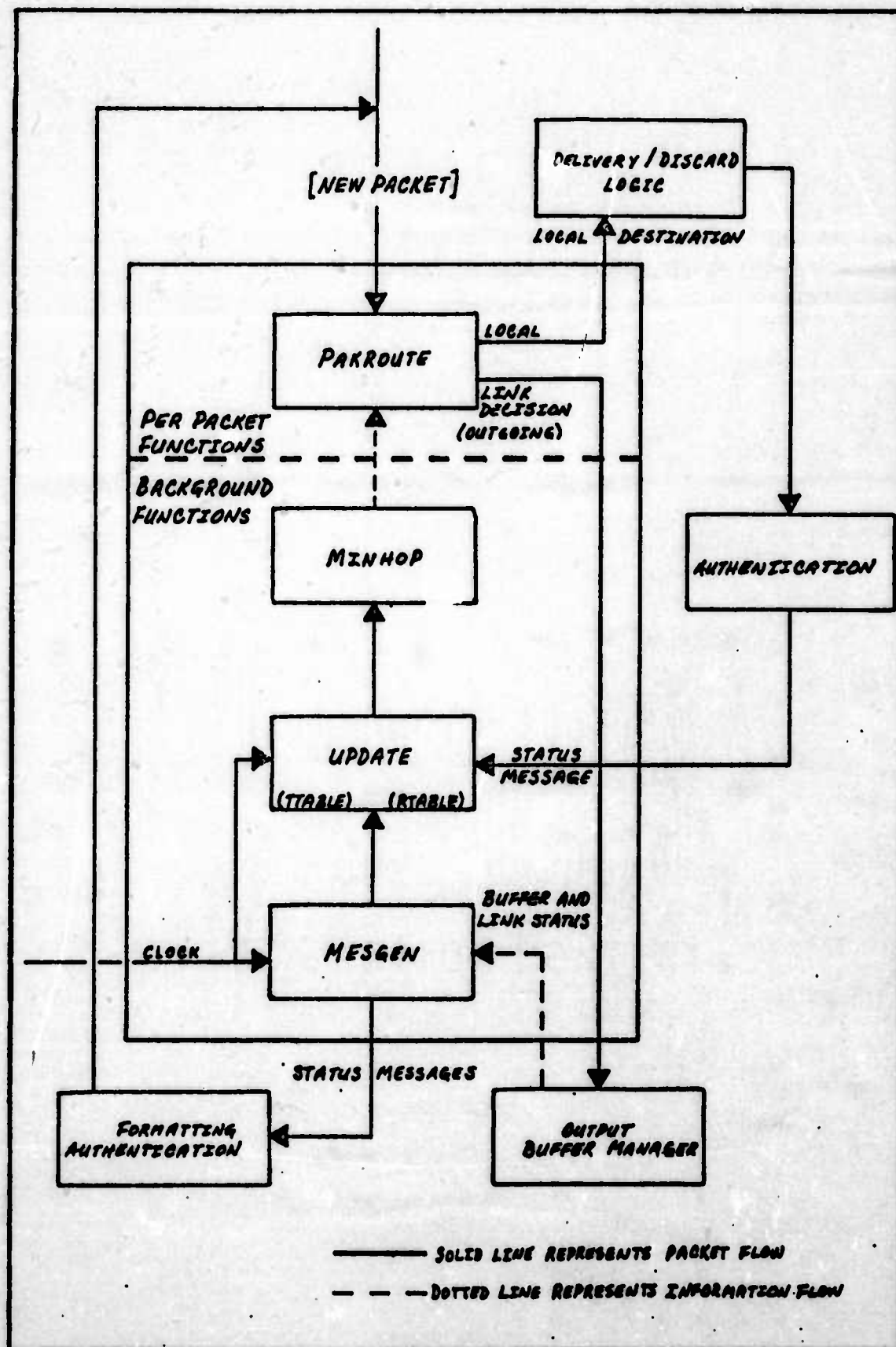
Fig 6. Overview of Routing Module   (Ref 2:A-4)
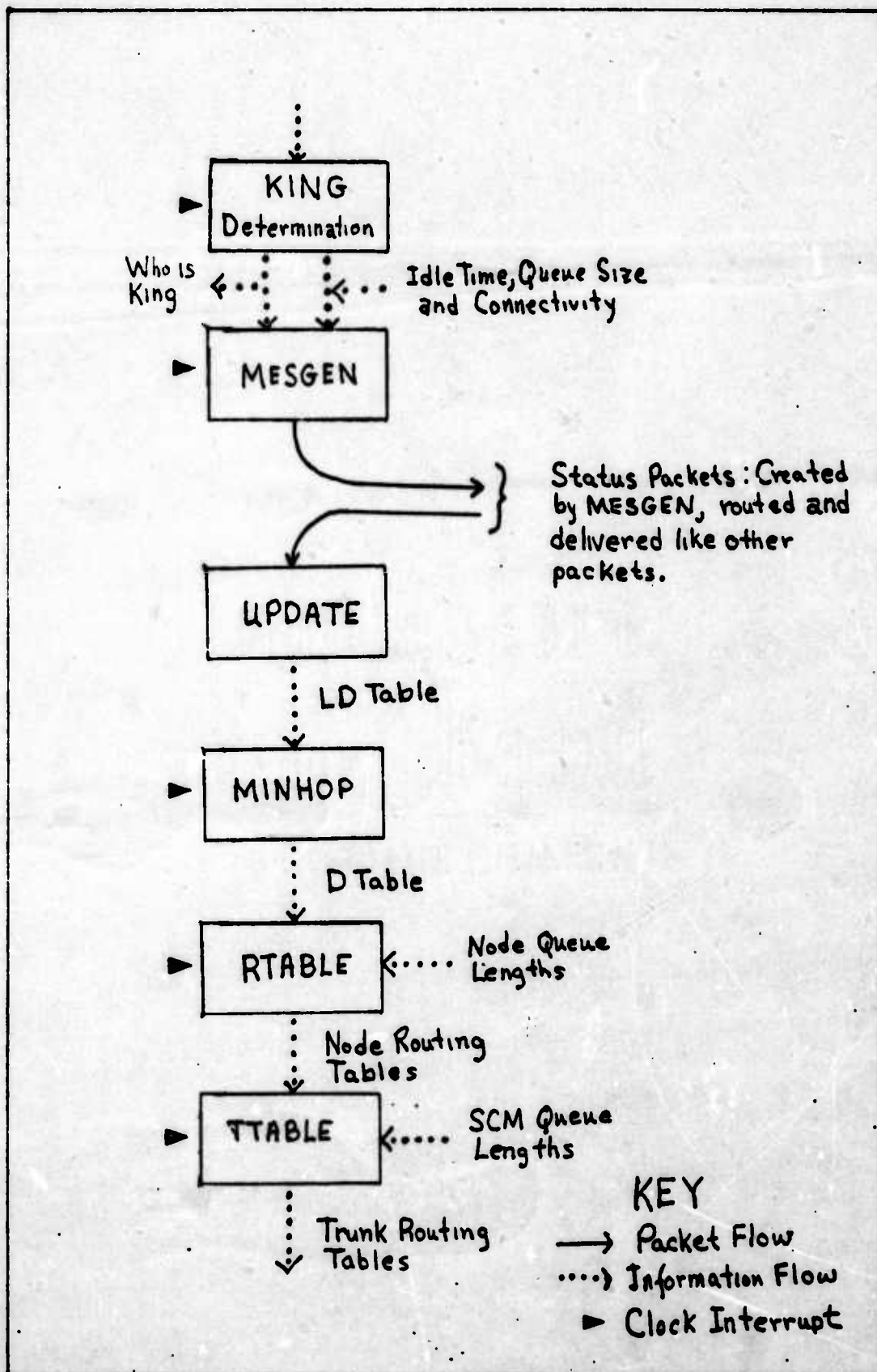
Fig 7. Schematic View of Background Tasks

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of a link to use is determined. The background functions, performed by MESGEN, UPDATE, MINHOP, RTABLE and TTABLE modules, develop the node-to-node and trunk routing tables.

The background tasks need not be performed by each SCM in a node, and MESGEN (the module which generates status packets to other nodes) must only be accomplished by one SCM. Otherwise duplication of status packets could flood the network. Thus, one SCM in each node will be designated as "king" and be responsible for implementing the background tasks and notifying the other SCMs within the node of changes in the routing tables. The king will be periodically determined in a distributed fashion as the SCM having minimal load. This will distribute these background tasks to the processor with the smallest current load. Each SCM must determine the same king SCM. In the case of a failure of the king SCM, the next king will take over the background functions (Ref 7:4).

To provide the king with the necessary information, and for each SCM to determine a common king SCM, the SCMs within a node will exchange vectors containing (Ref 7:4).

1. the processor utilization during a time interval and/or other estimates of the current processor load

2. the input queue size for processing at the SCM

3. the output queue sizes for each of the trunks emanating from the SCM with minimal prosessor utilization.

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Figure 8 shows the process each SCM goes through to determine the next king and when and how to exchange vectors.

MESGEN

The MESGEN module checks for changes in the connectivity and congestion of the node and, if a change exists, sends status packets containing the node's current status to all other nodes in the network. The flowchart of MESGEN is shown in Figure 9. A link is congested whenever the average number of packets over all trunk output queues in the link is greater than a threshold t1. A node is considered to be saturated whenever the total number of packets in the node input queue exceeds a threshold t2. When a node is saturated, all outgoing links are considered congested. MESGEN is executed periodically at two different time intervals, FTICK and STICK. When executed as a result of FTICK (100 milliseconds), "bad news" is checked, that is, if the congestion or saturation thresholds have been exceeded since the last FTICK or if a trunk, link or SCM have gone down since the last FTICK. When executed as a result of STICK (400 milliseconds), "good news" is checked, that is, if the congestion and saturation levels are within the thresholds since the last FTICK or STICK or if a connectivity within the node which was down is now up. Again, only if a change in the node connectivity or congestion and saturation levels is found at FTICK or STICK intervals will status packets be
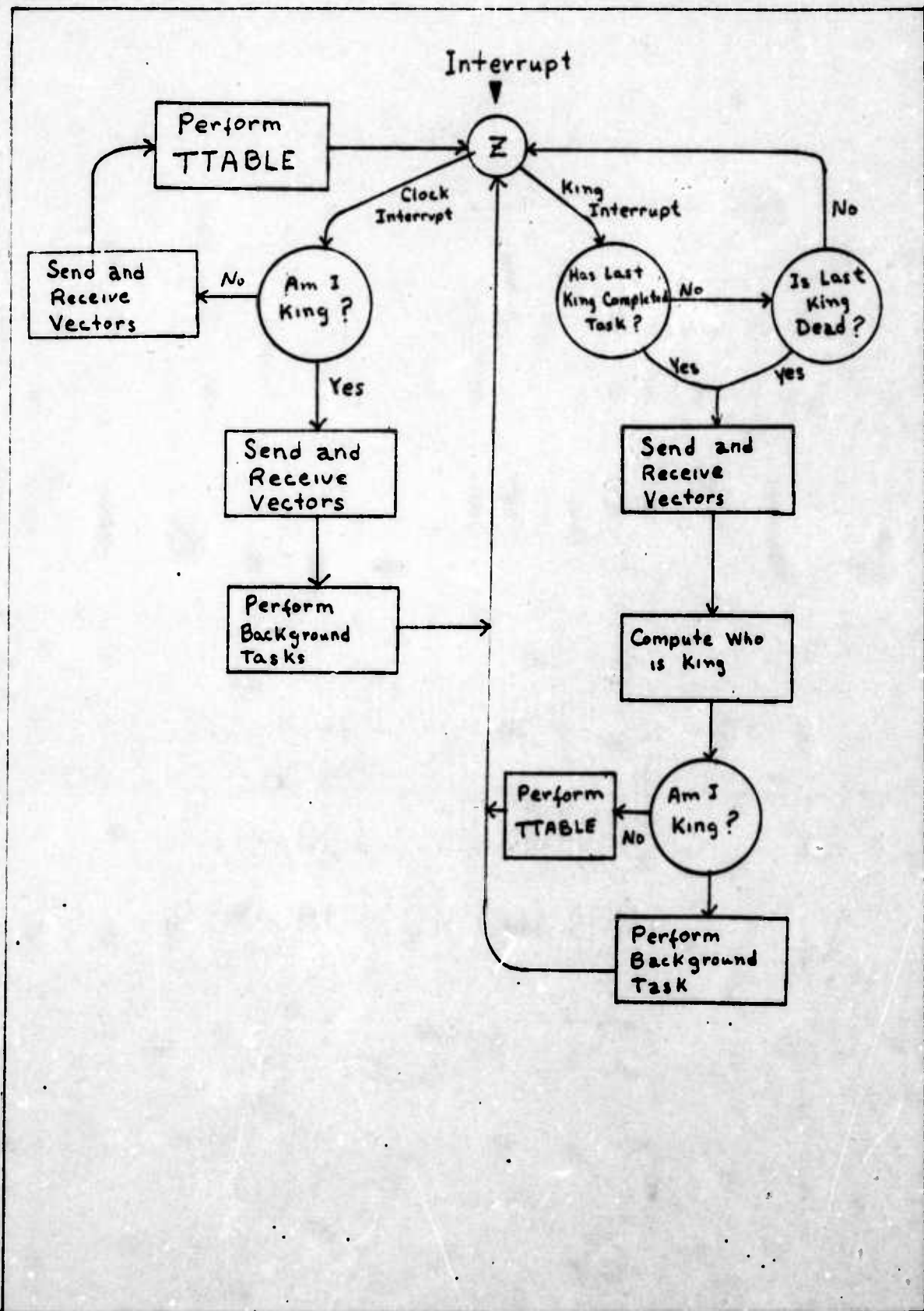
Fig 8. King Process and Background Timing

28.
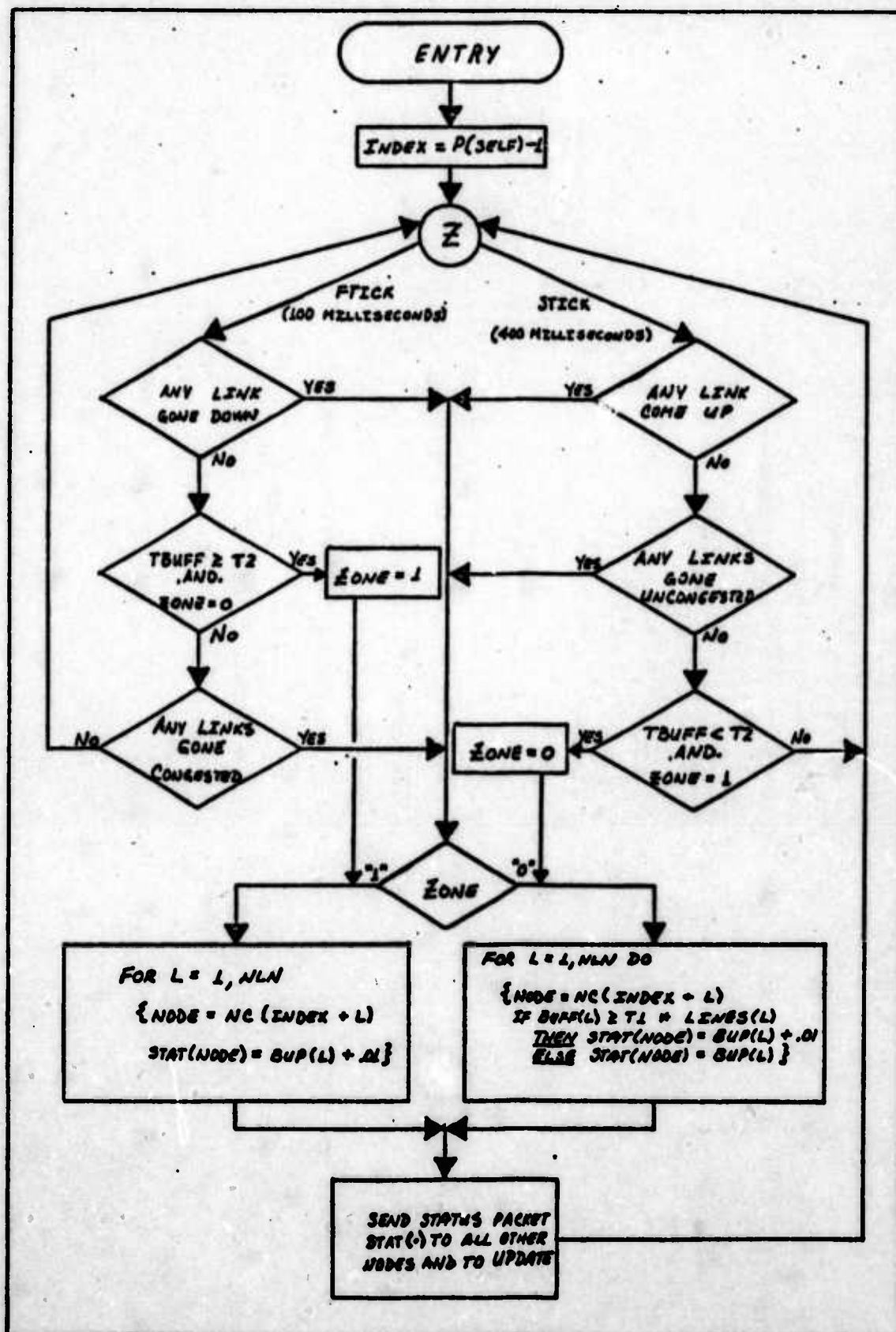
Fig 9.   MESGEN

generated and sent to other nodes in the network. If a change
is found a copy of the status packet will be sent to the
UPDATE module for local (nodal) processing.

UPDATE

The UPDATE module processes status packets received from
other nodes or from other SCMs within the same node. When
a status packet is received from another node, the SCM at
which it arrives executes UPDATE and sends copies to the
other SCMs in the same node. Each arriving status packet is
checked to see if it contains a change from the existing
information in the LD table. If a change does exist the LD
table is updated and a flag is set to indicate a change has
occurred. The MINHOP, RTABLE and TTABLE modules are then
executed. Figure 10 describes the procedure of UPDATE.

RTABLE

The RTABLE module uses the information in the distance
(D) table and queue length data in the node's links to main-
tain the two routing arrays, SROUTE and ROUTE. The SROUTE
array contains the minimum hop or minimum hop plus one paths
to determine the next path for a packet entering at a source
node. The ROUTE array contains the minimum hop paths to
determine the next path for a packet entering a tandem node.
Both arrays are N x 1 arrays, where N is the number of nodes

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Fig 10.   UPDATE

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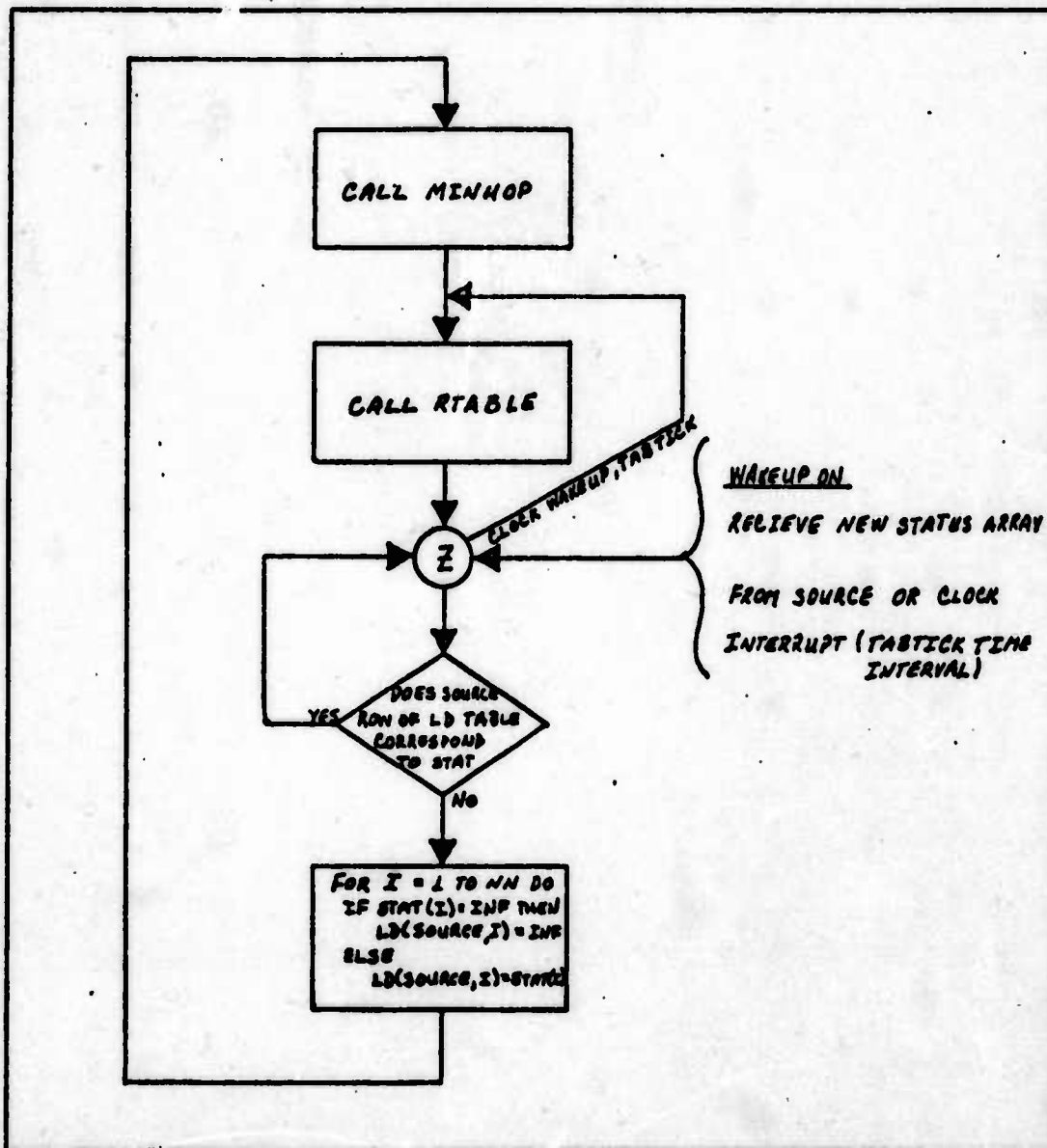
in the network. An entry in either array contains the link over which a packet will be routed next. The rationale behind having two routing arrays is based on the idea that under normal operating conditions a packet will encounter at the most only one tandem node because of the network connectivity. The source node could have multiple "best" routes to select from to get the packet to its destination, but a tandem node, in general, would have only one "best" route which would be the link directly connecting it to the destination node (Ref 4:32). The RTABLE procedure is shown in Figure 11.

TTABLE

TTABLE is the module used to build the trunk routing tables. These tables contain the trunks over which packets are to be routed, given a selected output link from SROUTE or ROUTE. The TTABLE algorithm and its associated array were not specified in the SCI documents. But from a description of the algorithm (Ref 6:38-39), a TTABLE module was developed by the authors to more fully exercise the routing algorithm. The trunk is selected based on the minimum packets in the output queues of all trunks in the selected link.

MINHOP

Fig 11. RTABLE

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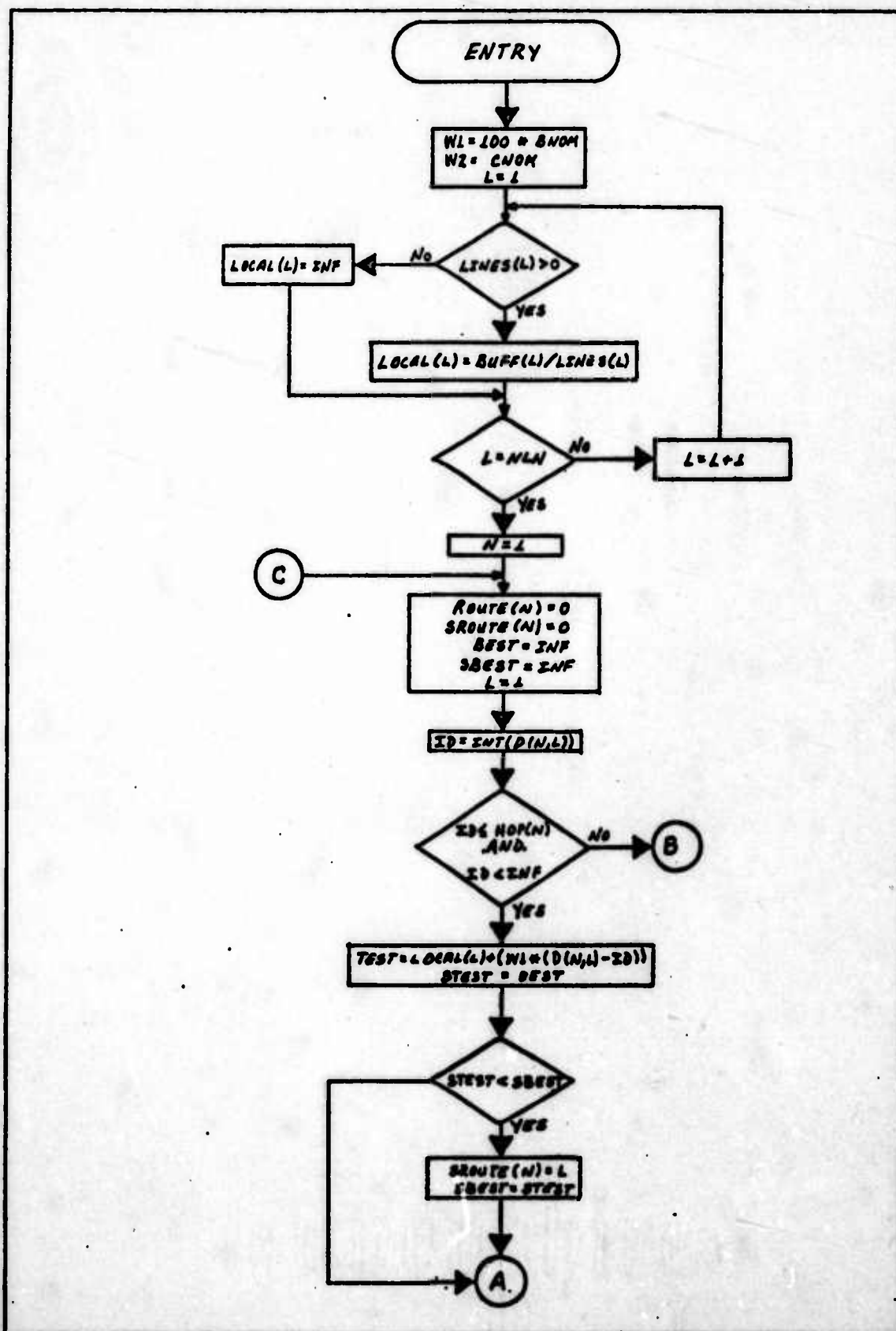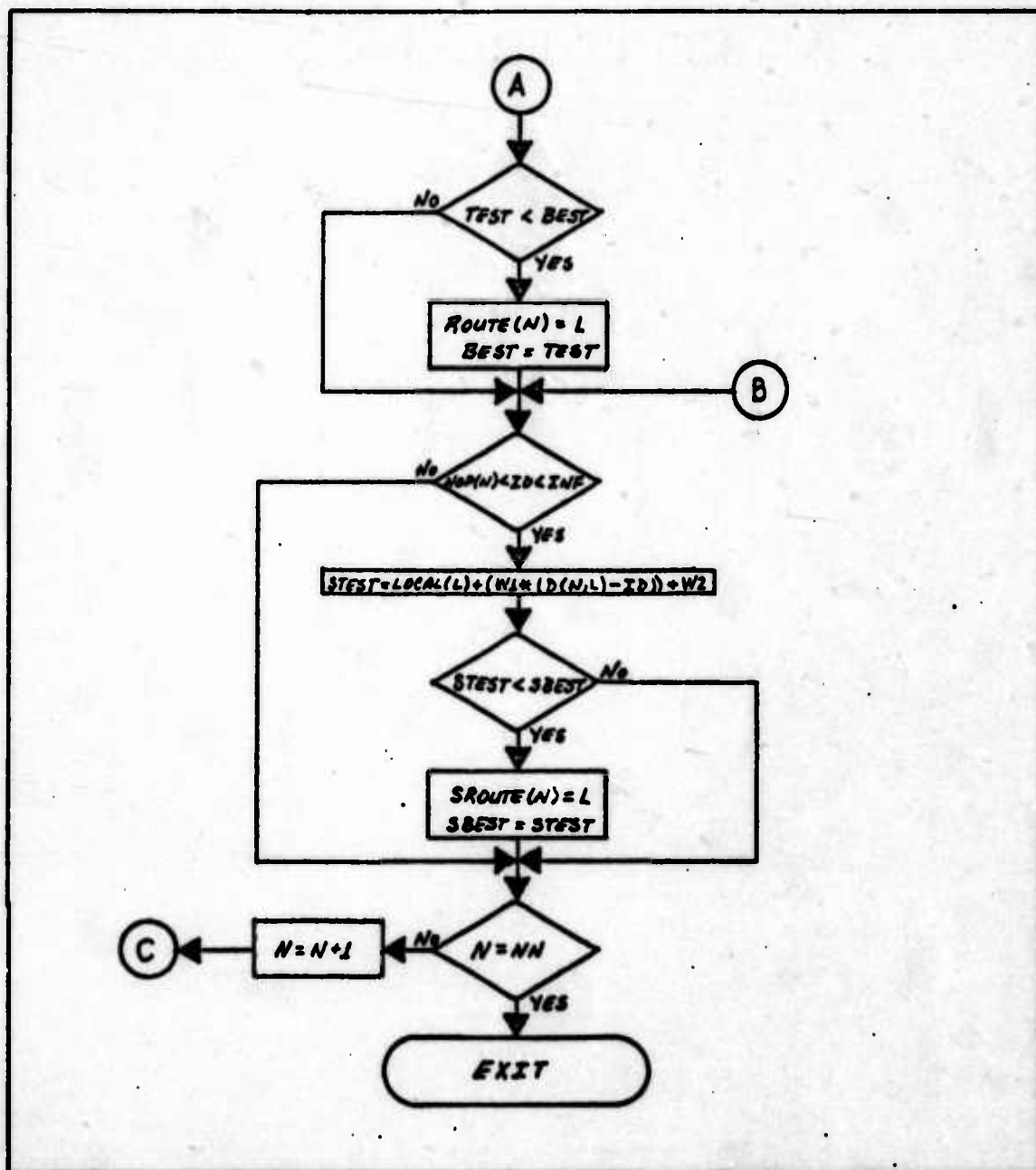
Fig 11. (CONT'D)

The MINHOP module is the "heart" of the routing algorithm (Ref 2:A-9) . It calculates the entries of the D table which, again, reflects the number of hops (plus a constant of .01, if congestion exists) required to reach another node on a particular link. This table contains only minimum hop and minimum hop plus one values. The entries are infinite if the hop count exceeds the minimum hop plus one. MINHOP consists of five processes: CONNECTIVITY, CONN-CHANGE, INIALIZE-D, COMPUTE-D, and INCREMENTAL-D, briefly described below.

CONNECTIVITY

CONNECTIVITY is used for initial computations of the connectivity pointer (P) array and the connectivity vector (NC) array. An example of the P and C arrays are shown in Figure 12. The P array is an (n+1) x 1 array representing the nodes in the network whose entries point to elements in the NC array. The NC array is an NL x 1 array, where NL is the number of one way links in the network. Each entry in the NC array corresponds to the destination node of each link from an initial node. The P and NC arrays are computed from the LD table to provide equivalent but more convenient informational form (Ref 2:A-9) . CONNECTIVITY is executed only when gross modifications in the network require it, that is, upon adding or permanently deleting nodes or links, or upon initialization (Ref 7:25).
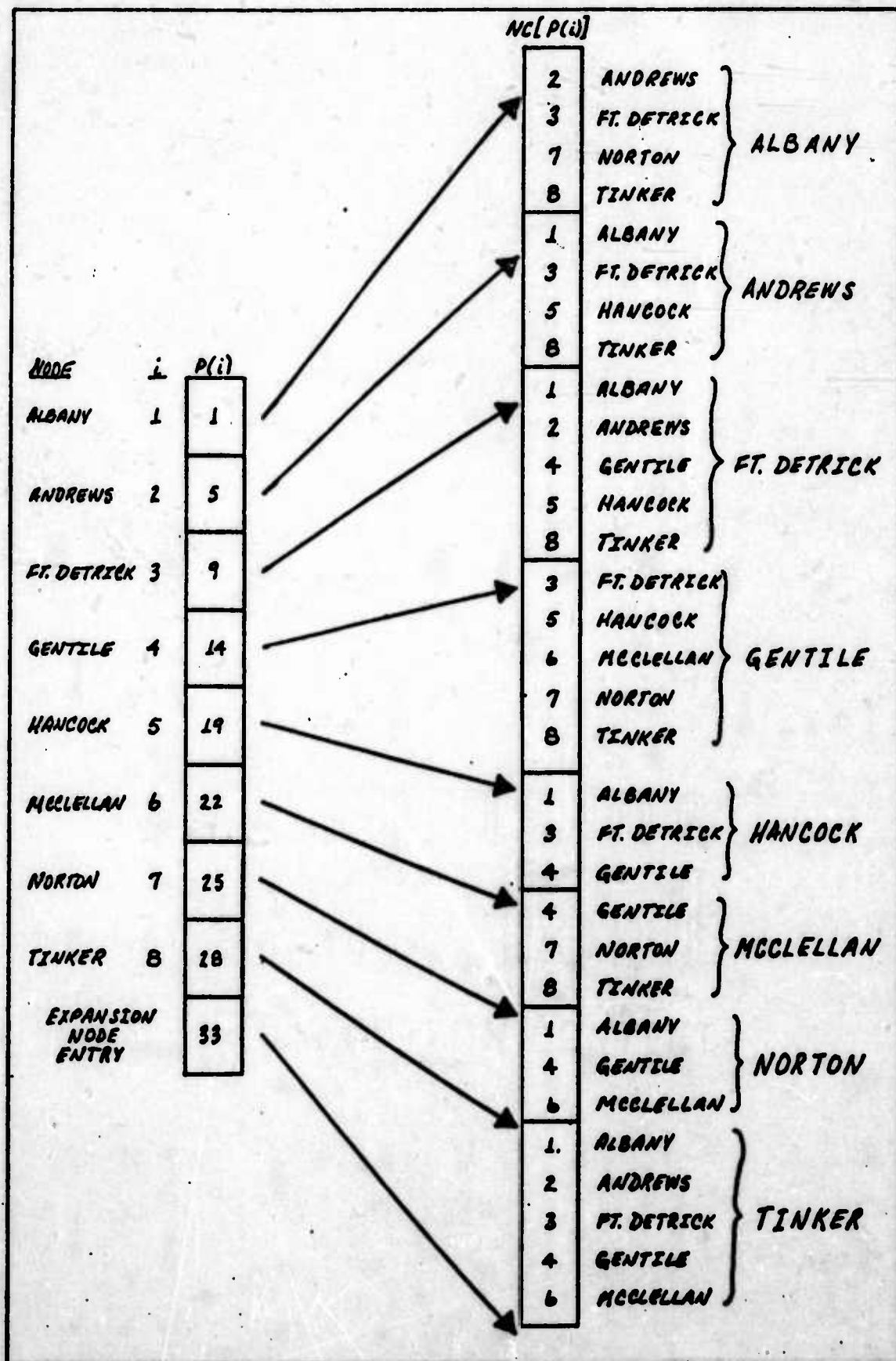
Fig12. P and NC Arrays

CONN-CHANGE

CONN-CHANGE is used to update the NC array and the corresponding entries in the LD table to reflect a link failure or repair or other minor network modifications. This procedure is faster than performing the CONNECTIVITY procedure and will be used to update the NC array most of the time.

INITIALIZE-D

INITIALIZE-D initializes the entries in the D table using entries from the LD table and the P and NC arrays. As with the P and NC arrays in the previous two processes, INITIALIZE-D and COMPUTE-D initialize and maintain two arrays, LIST and HOP, to provide network data in a convenient informational form. The LIST array is an N X 1 array where NLN entries are the nodes connected to the subject node and the other N - NLN - 1 entries are the nodes not connected. The authors could not find any use of this array in the routing modules and found the array dimensioned incorrectly in (Ref 2:A-15). The HOP array is an N X 1 array whose entries contain the minimum number of hops required for a packet to reach a particular node (if the entry is for the subject node the value is zero). An example of the LIST and HOP arrays are given in Figures 13 and 14.
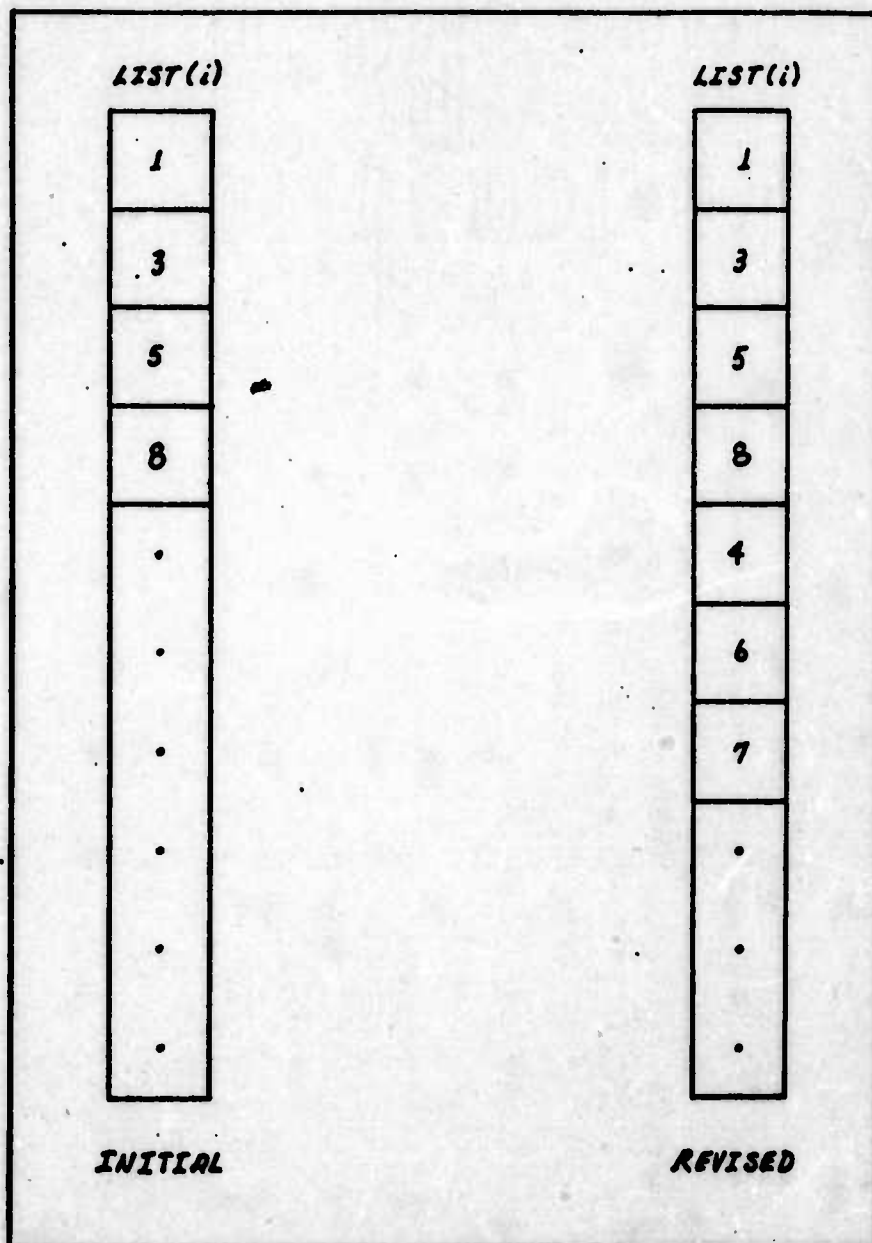
Fig 13. LIST Array for Andrews

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Fig14. HOP Array for Andrews

COMPUTE-D

COMPUTE-D completes the computations of the D table and the LIST and HOP arrays.

INCREMENTAL-D

INCREMENTAL-D is a procedure that is entered when only a congestion status change is reported. For a congestion status change it performs the same function as the INITIALIZE-D and COMPUTE-D processes but in much less time. Initializing the D table and LIST and HOP arrays and updating them for connectivity status changes must be performed by the INITIALIZE-D and COMPUTE-D modules. Since congestion reports are much more frequent than connectivity change reports, the INCREMENTAL-D saves a significant amount of processing time (Ref 7:33).

Per Packet Function

The per packet function determines the path a packet will take to reach its destination through a single module, PAKROUTE. PAKROUTE is executed for every packet entering the SCM. Figure 15 shows a flowchart of the per packet routing tasks. The routing tables developed by RTABLE and TTABLE are used to determine which outgoing link and trunk, if any, will be used.
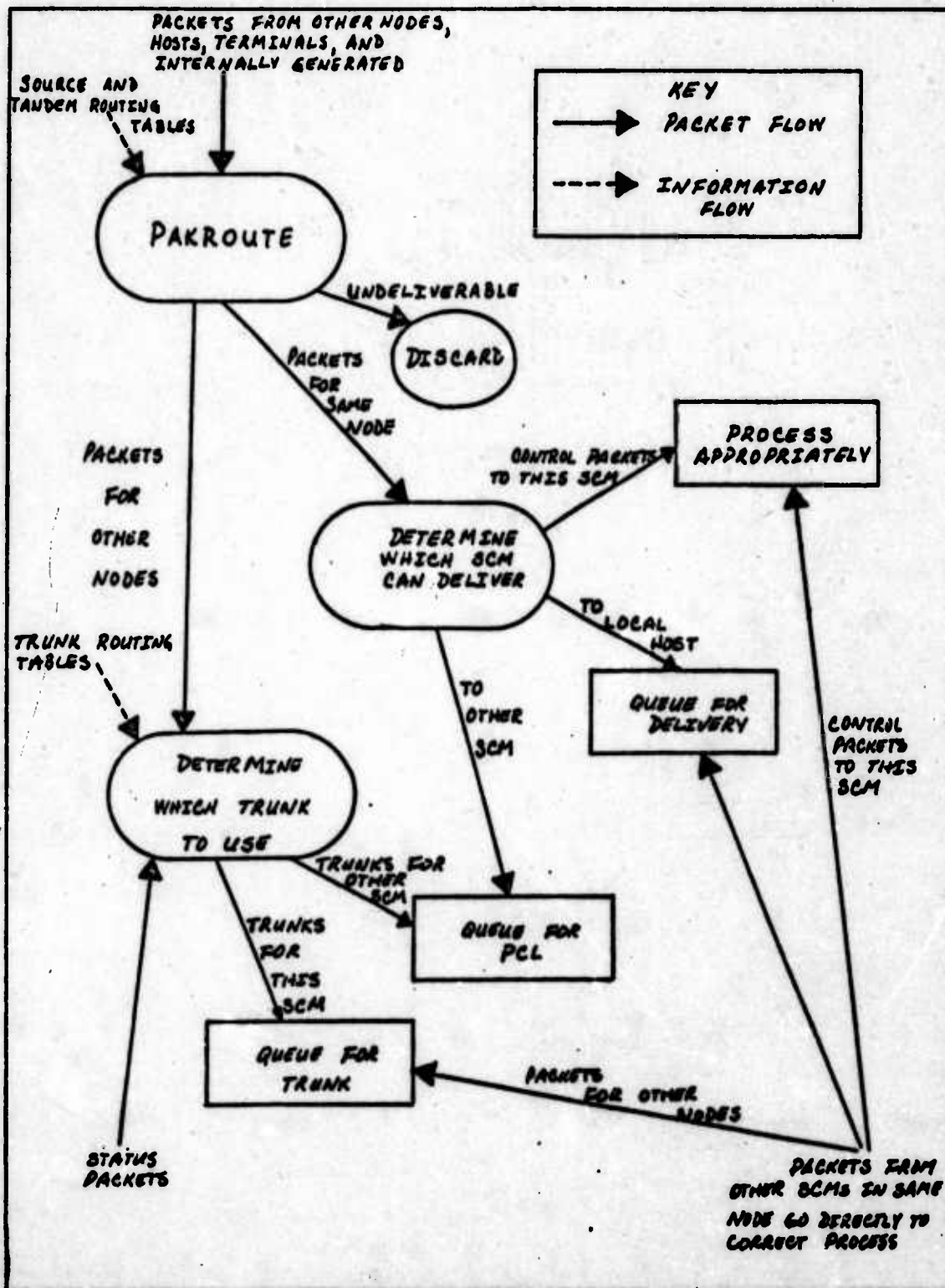
Fig 15. Schematic View of Per Packet Tasks

PAKROUTE splits the packets into three broad categories:

1. Packets destined for other nodes,

2. Packets destined for the present node,

3. Undeliverable packets (due to hardware failures separating part of the network, etc.)

Figure 16 shows the PAKROUTE module overview. PAKROUTE determines the path packets will take by first selecting the outgoing link through a table (ROUTE and SROUTE) lookup. The ROUTE and SROUTE tables are produced by RTABLE in the background functions. Secondly, the outgoing trunk is selected by another table (TROUTE) lookup. TROUTE (not shown in Figure 16) is produced by TTABLE in the background functions. Packets arriving at an SCM from another SCM in the same node can be queued directly to the correct trunk, that is, it is not necessary for a packet to process through two or more SCMs in the same node even when the appropriate trunk is connected at another SCM in the node. PAKROUTE is a simple module, however, it is executed for every packet which enters the SCM.

WAKEUP ON
PACKET RECIEVED
(I = DESTINATION, S = SOURCE)

Z

I = SELF — YES → LOCAL DELIVERY

NO

K = ROUTE(I) ← NO — S = SELF — YES → K = SROUTE(I)

K = 0 — YES → DISCARD (UNDELIVERABLE)

NO

PUT ON OUTGOING TRUNK K QUEUE
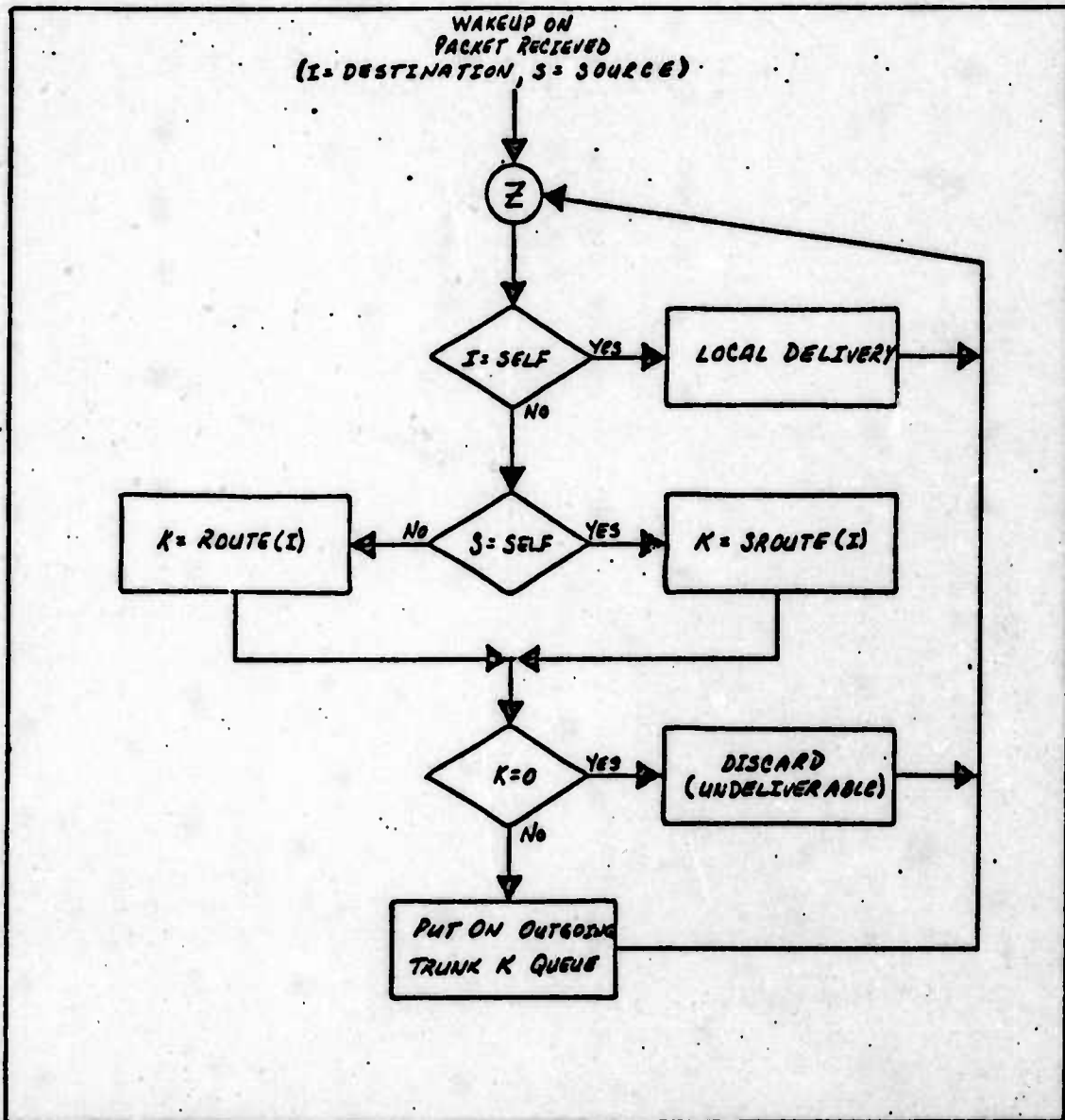
Fig 16.   PAKROUTE   (Ref 2:A-5)

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CHAPTER 4

AUTODIN II SIMULATION

Constraints and Parameters

The AUTODIN II simulation model described in this
chapter was developed to fill a void left by other AUTODIN
II simulations. Rockwell International simulated a single
Packet Switching Node (PSN), including Switch Control
Modules (SCM), Terminal Access Controllers (TAC), and Line
Control Modules (LCM) (Ref 3). Systems Control, Inc. and
Capt. J. Whittenton simulated the complete network but only
down to the Packet Switching Node (PSN) level (Ref 4; and
6:C1-C11). Input, output and processing control for the
network, however, is accomplished at the SCM level. There-
fore, the simulation developed as a part of this thesis
models the AUTODIN II network down to the SCM level.

The model is limited to the network itself and does
not include any provision for simulating external host
computers and TAC line connections. Source packets are
introduced at the SCM input queue. The network model
maximum limits are eight PSNs, 25 SCMs, and 125 transmission
lines. Any smaller configuration may be simulated. Any

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single PSN may contain from one to five SCM's. Each SCM

has one input queue (input line connection) and from one to

five output queues (output line connections). The simula-

tion model is constructed using the capabilities of the

Q-GERT simulation language and is established through standard

Q-GERT control statements and user supplied parameters.

The objects which will be tracked through the simula-

tion, to provide statistical information concerning the

AUTODIN II routing algorithm and modelled network, are

Q-GERT transactions. These packets should not be confused

with AUTODIN II packets.

> As an introduction to Q-GERT network modelling
> let us consider a one server system in which a single
> line of items forms before the server. The server
> of the system has a status: busy or idle. The
> server status changes as system conditions change.
> The server is busy when he is processing an item,
> otherwise he is idle. The items flow through the
> system. They arrive, possibly wait, are served,
> and depart the system. Such a sequence of events,
> activities and decisions is referred to as a pro-
> cess. Entities that flow through a process are
> called transactions. Thus, items are considered
> as transactions. A transaction can be assigned
> attribute values that enable a modeler to dis-
> tinguish between individual transactions of the
> same type or between transactions of different
> types. For example, the time a transaction enters
> the system is an attribute of the transaction
> (Ref 8).

The characteristics of AUTODIN II packets are imposed

upon Q-GERT transactions. Therefore, the

arrival and flow of AUTODIN II packets is modelled by the

generation and flow of Q-GERT transactions. When a trans-

action is discussed as an item flowing through Q-GERT it

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will be called a Q-GERT transaction. When a transaction is
discussed as an item flowing through AUTODIN II it will be
called an AUTODIN II packet.

The packet flow may be separated into two segments
for statistical tracking. This is done by placing the
proper values in user supplied parameters. The capability
was supplied to allow tracking a specific portion of AUTODIN
II traffic against a background of all other traffic (see
the NORAD scenario in Chapter 8), but can be used for other
purposes.

The remainder of this chapter will describe the Q-GERT
model of a Switch Control Module, and the User Input (UI),
User Function (UF), User Subroutine (US), and User Output
(UO), FORTRAN subroutines written to model the AUTODIN II
routing algorithm.

Q-GERT

Only those portions of the Q-GERT simulation language
which were used in the AUTODIN II model will be described.
Anyone wishing more information concerning Q-GERT should
refer to "Modeling and Analysis Using Q-GERT Networks" by
A. Alan B. Pritsker (Ref 8).

There are two basic types of symbols used in Q-GERT
networks. These are ovals, used to represent simulation
nodes (not to be confused with AUTODIN II packet switch-
ing nodes), and lines, representing activities. A node

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can represent a queue or be a branching point for simulation transactions. Activities occur between nodes, act as connections between nodes, and can accumulate time. Activities represent services rendered. Activities in the AUTODIN II model are used to accumulate SCM processing time and line transmission time.

The Q-GERT oval length is divided into three sections. The first section is divided into an upper and a lower portion. The top portion of a regular node (also source and sink nodes) contains the number of Q-GERT transactions which must enter the node the first time to cause a Q-GERT transaction to leave the node. The lower portion contains the number of Q-GERT transactions which must enter the node thereafter to release a transaction. The top portion of a Q-node contains the initial number of transactions in the queue and the lower portion is the number of transactions the queue can hold.

The middle section of a Q-node identifies the queueing discipline which is used within the queue. In a source node, it identifies the arrival rate for transactions. In regular or sink nodes, the middle section decides whether or not statistics will be collected at the node. The final section contains the identification number of the node.

The AUTODIN II model consists of three different Q-GERT networks. Network N1 in Figure 17 is the clock which establishes the FTICK and STICK time intervals discussed in the

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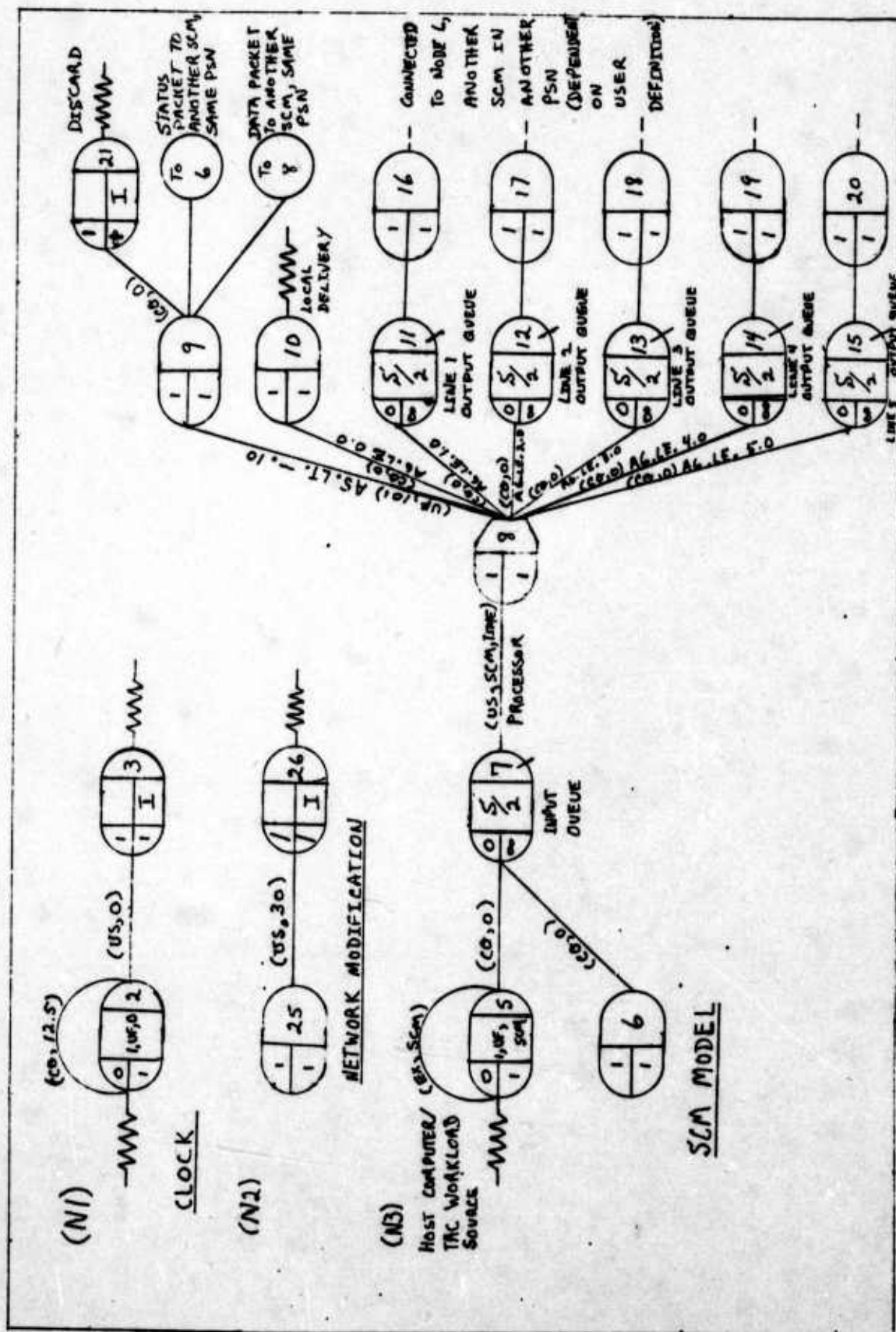
Figure 17 - Q-GERT Model of an SCM

description of MESGEN in Chapter Three. The basic time unit
for the clock is one millisecond. The clock consists of a
source node, an activity, and a sink node. The source node
is identified by the jagged line entering it, while the sink
node is identified by the jagged line leaving it. This is
true of all source and sink nodes. The first time the source
node becomes active it does not need a simulation transaction
to activate it. The zero in the upper left portion of the oval
signifies that this node can become active the first time
without a Q-GERT simulation transaction. Thereafter, a trans-
action is required to activate the source node, as signified
by the one in the lower left portion of the oval. When the
node is activated, it generates transactions along all activi-
ties extending from the right portion of the oval. One of
these activities returns to the left portion of the oval, and
therefore, during the first activation, and subsequent acti-
vations, the source node generates the transaction which acti-
vates it next. The transaction traversing the loop activity is
given a time delay of 12.5 milliseconds. This time delay was
chosen to divide a 100 millisecond time interval into eight
segments, so that for each Packet Switching Node, FTICK
and STICK processing would occur at a different time. This
simultaneous occurrence could cause simultaneous generation
of AUTODIN II status packets at all nodes and was considered
unrealistic by the authors.

   While the source node is active a call is made to user

subroutine UF (portrayed in the central portion of the oval)
and a parameter of zero is passed to that subroutine. This
subroutine controls updating of the clock. The actions that
occur due to the call will be discussed in the section con-
cerning subroutine UF. Finally, there is an identification
number in the right portion of the node.

An activity extends from the clock source node to the
clock sink node. Transactions generated by the source node
traverse this activity. In so doing they cause a call to
user subroutine US and a parameter of zero is passed to
that subroutine. This activates the message generation
routine MESGEN. The actions resulting from the call will
be discussed in the section concerning Subroutine US.

The clock sink node requires a transaction for every
activation, including the first one. This is signified by
the two ones in the left portion of the oval. The I in
the lower middle portion of the oval identifies it as a
node that collects interval statistics and its identifica-
tion number is three.

The second network, N2, in Figure 17 allows modification
of AUTODIN II network parameters (such as the rate packets
arrive in the network, whether lines are up or down, priority
and short packet percentages, and others) during the running
of the simulation. N2 consists of a basic Q-GERT node, an
activity and a sink node. The initial node requires a trans-
action for every activation, but has no entering activity.

Transactions which activate this node are generated in user subroutine UI and will be discussed in the section about Subroutine UI. Transactions traversing the activity from node 25 (the initial node's identification number) cause a call to user subroutine US and a number 30 is passed to that subroutine as a parameter. The final node in N2 is the sink node, which acts in the same fashion as node three in network N1.

The final network, N3, represents an SCM, and occurs in multiple copies, one for each SCM (up to 25), but all copies are the same except for identification numbering. Q-GERT provides a method for creating multiple copies of portions of a simulation model which are similar (minor differences are allowed). This method was used to provide for multiple SCMs.

The SCM contains a source node, six queue nodes, a branching node, six basic nodes, and two sink nodes plus all connecting activities. The source node (node 5) generates the traffic which would come into this SCM from terminal access controllers and host computers. A call is made to user subroutine UF where AUTODIN II packet parameters become a part of the generated transaction. These parameters include priority, type of packet (long or short), source and destination Switching Control Modules, and for which segment of traffic the statistics are gathered. An activity, which does not delay the transaction, connects node five

to node seven. This activity is a dummy and provides only a
connection. A basic node, number six, is also connected to
node seven by the same type of activity. Node six represents
the input connection for lines from SCMs which are contained
in other Packet Switching Nodes.

Node seven represents the input queue at this Switching
Control Module. It is a Q-GERT queue node and is recogniz-
able by the tail at the lower right of the node oval. The
infinity symbol in the lower left of the oval identifies the
queue limit as infinite. The S identifies the queue order
as ranking by priority and the two beneath the S states that
parameter, or attribute, two is the priority parameter. The
activity which follows node seven represents the SCM processor
and does provide a time delay to transaction traversal. Since
a queue node will not release a transaction to an activity
until that activity is clear, the processor delay will cause
transactions to back up in the input queue.

Activity seven calls subroutine US, passing it the identi-
fication number of the SCM this portion of the Q-GERT network
represents. Further routing of the transactions within the
Q-GERT network is determined here, and a processor delay time
is returned to the activity.

Node eight is a branching node. This is evidenced
by its shape and by the number of activities leaving it.
The conditions for branching, which are listed one to an
activity, are tested beginning with the top activity and

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proceeding to the bottom activity. The first activity with a condition which tests true receives the transaction.

If transaction attribute five is less than -.10, the transaction will traverse the activity connecting node eight to node 9. A call will be made to user subroutine UF and a parameter of 101 passed to it during that traversal. User subroutine UF will determine whether the transaction should be discarded (passed to sink node 21) if it cannot be delivered, should be treated as an AUTODIN II status packet for another SCM in the same node, or should be treated as an AUTODIN II data packet for another SCM in the same node. If one of the last two decisions is reached, Subroutine UF will make the connection to route the transaction to the proper copy of the Q-GERT SCM model; to node six or node eight in that copy. If attribute five is equal to or larger than -.10 condition testing will continue.

If transaction attribute six is less than or equal to zero, the AUTODIN II packet which is represented by the Q-GERT transaction should leave the AUTODIN II network from this SCM. It is therefore sent to sink node ten, which is labeled "Local Delivery".

The remaining five branches from node eight have identical functions and will be described in common. Transaction attribute six, for any transaction selecting one of these activities, represents the transmission line over which the corresponding AUTODIN II packet would be routed. Nodes 11

through 15 are queue nodes and correspond to the AUTODIN
II output queues for lines one through five. The activities
which connect nodes 11 through 15 to nodes 16 through 20
all call user subroutine UF, passing it a parameter value
102. A transmission delay for the specified line is returned
to the activity. After the delay time is complete, the trans-
action representing an AUTODIN II packet will pass through
the appropriate basic node (16-20) to node six of the SCM to
which that transmission line is connected. The total network
line configuration is established by user input parameters
to user subroutine UI and will be discussed in the next section,
which describes that subroutine.

The Q-GERT network described here is deceptively simple
since many of the functions of the simulation are performed
in user subroutines UI, UF, US and UO. The functions con-
tained in those subroutines correspond to the functions MESGEN,
UPDATE, MINHOP, RTABLE, TTABLE and PAKROUT described in Chap-
ter Three. The following four sections describe the contents
of UI, UF, US and UO.

Subroutine UI (User Input)

Subroutines UI, US, UO and function UF are placed in the
Q-GERT simulation language to provide a means by which Q-GERT
users could insert their unique processing requirements.
Since Q-GERT is written in FORTRAN these processes also should
be written in FORTRAN. This is true for Q-GERT simulation in

general. Subroutine UI is called by processing internal to the Q-GERT simulation language after the standard Q-GERT network configuration input is processed. UI allows the simulation user to read in any user unique data records which will effect the Q-GERT network processing and to accomplish any processing initialization the user requires. A return must be made from UI to the calling process before any simulation transactions can be generated.

Early in the development of the AUTODIN II simulation model a decision was made to configure the network as much as possible through user input parameters. Therefore, six types of user input records were developed. Four of these (types 001 through 004 - Tables I through IV) establish the initial AUTODIN II network configuration for each simulation run. The remaining two (types 900 and 910 - Tables V and VI) provide the ability to vary selected parameters of the network while the simulation is in progress.

Card types 001 through 004 are required for each Switch Control Module. They provide the basic description of that SCM and the Packet Switching Node that contains it.

Each of the user input records contains the identification numbers of the Switch Control Module and Packet Switching Node which it's data describes. These are identified as ISCM and INODE in the record. The type 001 record also contains the number of Switch Control Modules in the Packet Switching Node specified. This number is used to insure the

TABLE I

CARD TYPE 001 FORMAT

FORTRAN Label	Card Columns	Contents
ISCM	1-2	SCM identification number
INODE	3-4	PSN identification number
INRSCM	5-6	Number of SCMs in this PSN.
GNMCHRS	7-16	The normal, or general, traffic rate originating at this SCM, in millions of characters per hour.
SHRTPKT	17-19	The proportion of total packets originating at this SCM, to be identified as a short packet.
ICONSCM	20-21 22-23 24-25 26-27 28-29	Other SCMs connected by trunk to this SCM.
SPMCHRS	30-38	Special, or identified, traffic originating at this SCM, in millions of characters per hour.
LINDLA	39-43 44-48 49-53 54-58 59-63	The number of miles between this SCM and other connected SCMs (the mileage must be in the same order as the connected SCMs in ICONSCM described above).
PRECDNC	64-66 67-69 70-72 73-75	The proportion of packets to be assigned to each precedence level (highest level to lowest level, respectively).
CRDTYPE	78-80	Type of card (001)

TABLE II

CARD TYPE 002 FORMAT

FORTRAN Label	Card Columns	Contents
ISCM	1-2	SCM identification number
INODE	3-4	PSN identification number
NODTRAP	44-48	Proportion of traffic, originating at this SCM, destined for node 1.
NODTRP 2	49-53	Proportion of traffic, origi-
3	54-58	nating at this SCM, destined
4	59-63	for Nodes 2 through 8
5	64-66	
6	67-69	
7	70-72	
8	73-75	
CRDTYPE	78-80	Type of card (002)

TABLE III

CARD TYPE 003 FORMAT

FORTRAN Label	Card Columns	Contents
ISCM	1-2	SCM identification number
INODE	3-4	PSN identification number
SCMTRP1	44-48	Proportion of traffic, from node 1, to be locally delivered by this particular SCM.
SCMTRP2 3 4 5 6 7 8	49-53 54-58 59-63 64-66 67-69 70-72 73-75	Proportion of traffic, from nodes 3 through 8, to be locally delivered at this particular SCM.
CRDTYPE	78-80	Type of card (003).

TABLE IV

CARD TYPE 004 FORMAT

FORTRAN Label	Card Columns	Contents
ISCM	1-2	SCM identification number
INODE	3-4	PSN identification number
SATLEVEL	7-15	Saturation level for this SCM (node saturation level is determined by adding the SATLEVELs of all SCMs in the node).
CNGST1	39-43	Congestive level for the Link corresponding to ICONSCM on card 001.
CNGST2		Same as CNGST1
CNGST3		" " "
CNGST4		." " "
CNGST5		" " · "
CRDTYPE	78-80	Type of card (004)

TABLE V

CARD TYPE 900 FORMAT

FORTRAN Label	Card Columns	Contents
ISCM	1-2	SCM identification number
INODE	3-4	PSN identification number
LNSTAT1	20-21	Line status. LNSTAT (i)
LNSTAT2	22-23	must correspond in order
LNSTAT3	24-25	with ICONSCM on the 001 card.
LNSTAT4	26-27	Minus one is line down. Plus
LNSTAT5	28-29	one is line up.
LNCHTM1	38-43	The time (in milliseconds)
LNCHTM2	44-48	into the simulation run to
LNCHTM3	49-53	change the lines status as
LNCHTM4	54-58	indicated by the LNSTAT (i)
LNCHTM5	59-63	code.
CRDTYPE	78-80	Card Type (900).

TABLE VI

CARD TYPE 910 FORMAT

FORTRAN Label	Card Columns	Contents
ISCM	1-2	SCM identification number
INODE	3-4	PSN identification number
GNMCHRS	7-16	General traffic originating at this SCM (in millions of characters per hour).
SHRTPKT	17-19	Percentage of short packets originating at this SCM.
SPMCHRS	30-38	Special, or identified, traffic originating at this SCM (in millions of characters per hour).
TIME	39-43	The number of milliseconds into the simulation the action will take place.
PRECDNC	64-66	Four precedence (priority) levels.
	67-69 70-72 73-75	Probability of traffic for each SCM.
CRDTYPE	78-80	Type of card (910).

correct number of SCMs are established for each node and is used as a cross reference against the type 001 received for each SCM. Two fields provide the parameters for establishing arrival rates of AUTODIN II packets from sources outside the network to node five of the SCM model (see Figure 17). Both fields have units in millions of characters per hour. The first of those fields is identified as GNMCHI ` and represents the combination of all different types of traffic which can flow across the network. The second field is used to segregate a portion of the traffic and develop statistics on that portion only. This field is identified as SPMCHRS. The input unit of measure for these two fields was chosen to be understandable by users. The simulation, however, has a base unit time of one millisecond and a base unit transaction of a packet. Therefore, the input information must be converted to the correct unit of measure for the simulation by sub-routine UI. A reference to the transaction generation loop for node five (Figure 17) shows that an exponential (EX) distribution is being used to model source packet arrival. A mean interarrival time (time between arrival of packets) must be supplied to use this distribution. Since packets come in two sizes, 4704 bits and 600 bits (Ref 4:77), with eight bits to the character, the percentage either of short packets or of long packets must be known. The percentage of short packets is contained in the type 001 input record as a decimal figure and is identified as SHRTPKP.

The method for developing the equation to convert millions of characters per hour to interarrival time in milliseconds followed this reasoning:

1. Total bits/hr = (GNMCHRS + SPMCHRS) X 8 bits/char

2. Total bits/hr + (Total packets/hr X (1.00-percent short packets) X 4704 bits/ long packer) + (total packets/hr X percent short packets X 600 bits/short packet)

3. (GNMCHRS + SPMCHRS) X 8 = (total packets/hr X (1.00 - SHRTPKP) X 4704 bits/ long packet) + (total packets/hr X SHRTPKP X 600 bits/short packet)

4. Total packets/hr = (((1.00-SHRTPKP) X 4704 bits/ long packet) + (SHRTPKP X 600 bits/short packet))÷ ((GNMCHRS + SPMCHRS) X 8 bits/char)

5. Total packets/millisecond = total packets/hr ÷ 3,600,000 millisecond/hr

6. Interarrival time between packets = 1 ÷ total packets/millisecond

The final equation is:

Interarrival time = 3,600,000 milliseconds/hr ÷ (((1.00-SHRTPKP) X 4704) + (SHRTPKP X 600)) ÷ ((GNMCHRS + SPMCHRS) X 8)

This interarrival time is computed by Subroutine UI from SHRTPKP, GNMCHRS and SPMCHRS supplied by user in card type 001.

The short package percentage, SHRTPKP, is also used in function UF for assignment of type of packet code to attribute one.

The type 001 contains four precedence levels (priority) fields identified as PRECDNC. Each field contains the percentage (in decimal point form) of all traffic originating

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at that SCM which will carry the corresponding priority.
These percentages must add to 1.0 and are used in function
UF for assigning precedence code to attribute two of the
Q-GERT simulation transaction.

The remaining fields in the type 001 record establish
the network configuration and the transmission line mile-
age. There are five connectivity fields. Each one corres-
ponds to a line from this SCM and contains the identifica-
tion number of the SCM to which that line is connected. If
a line is not connected, the field is left blank. A check
is made that the connection between two SCMs is shown at
both SCMs. The NFTBU array (Ref 8:243) in the Q-GERT simula-
tion language processor is updated from this information to
establish the connections between Q-GERT SCM models (as
described in the preceding section). There are also five
mileage fields; one corresponding to each line. These fields
are used as part of the calculation which determines trans-
mission delay on outgoing lines from the SCM. This computa-
tion is done in PAKROUT, which is contained in subroutine UO.

The type 002 user record contains eight fields (excluding
the SCM and PSN identification number fields). Each field
contains the percentage of traffic originating at this switch-
ing control module which is to be sent to the corresponding
packet switching node, i.e. field one contains the percentage
(in decimal point form) which when multiplied by the total
number of packets gives the number to be sent to PSN one.

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These percentages and the percentages from the type 003 user record are used to establish a destination SCM percentage which is then used in function UF to assign destination SCM codes to attribute four of the Q-GERT simulation transaction.

The type 003 user record also contains eight fields (again, excluding SCM and PSN fields). These fields contain a decimal number which represents the percentage of traffic to this PSN originating at the PSN whose identification number corresponds to each field and which is directed to this SCM. Chapter One of the User Manual (Appendix A) provides an example of these percentages.

The type 002 and type 003 records establish, respectively, a 25 by 8 matrix and an 8 by 25 matrix. When a matrix multiplication is done using these two matrices, the result is a 25 by 25 matrix containing the percentage of all traffic at a specific originating SCM which will be directed to a specific destination SCM. As specified before, this matrix is used to establish destination SCMs for the Q-GERT simulation transaction. This is called the DISTRIB Table.

The type 004 user record for each SCM contains a saturation level field and five congestion level fields. The saturation levels (in number of packets in queues) for all SCMs in a PSN are added together to establish a saturation level for the PSN. Each of the congestion levels (in number of packets in queue) in each SCM represents the corresponding transmission line's output queue. When the simulation is in progress if

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the average of the contents of the output queues for a link exceeds the average of the congestion levels for the lines contained in the link, the link is declared to be congested. A link is defined as all the lines (trunk is used interchangeably with line) which connect one PSN with another PSN, no matter which SCMs within the two PSNs they connect. A congested link is weighted by the AUTODIN II routing algorithm so that it is used less often. When all input queue levels added together exceed the saturation level all links for that PSN are declared congested.

The type 900 and type 910 user records, as stated before, allow changes of parameters while the simulation is in progress. The type 900 transaction contains five line status change fields (one for each line in the SCM) and five corresponding status change time fields. A minus one in the line status change field means the line is going down, a plus one means it is coming up and a zero means no change. The corresponding change time field contains the number of milliseconds into the simulation at which the change is to occur. Each line status change field which is nonzero generates a Q-GERT transaction through use of the Q-GERT subroutine PTIN (REF 8:259) which is entered into Q-GERT node 25 (Figure 17) at the simulation time specified in the status change time field.

The type 910 record (Table VI) allows changes in GNMCHRS, SPMCHRS, SHRTPKP and the four PRECDNC fields and a recalculation of interarrival time. The structure of the 910

record is similar to the type 001 record. The type 910 also contains a time change field and the generation of Q-GERT transaction occurs in a manner similar to the ones generated for the type 900.

Several tables are generated and initialized from the data contained in user record types 001 through 004. The original data on the type 001 card is held in one of two arrays, depending on whether it was in real or integer format. These two arrays contain 25 lines each and are line indexed by SCM number. This gives such benefits as a cross reference from SCM to the PSN which contains it or from SCM to the SCMs which are connected with it by transmission lines.

There is also a PSN to SCM cross reference table (Table VII). The DISTRIB table has already been described (Table VIII). It is constructed from the two halves of the SCMEDIT table, which contains the information from the type 002 and type 003 user records (Table IX). There is a LINKS table (Table X) for each PSN. Each LINKS table contains 8 lines of 20 entries. Each line represents a PSN. The entrys in the table identify the transmission trunks which make up the link between the table owner PSN and the line PSN. The first entry in each line is the number of trunks in the link. The second entry is trunk one, the third is trunk two and so on, until all trunks are listed. Each entry contains four pieces of information. Positions

TABLE VII

PSN to SCM

PSN		SCM					
1	NODESCM	1	2	1000	1000	1000
	Number of SCMs					
2	NODESCM	3	4	1000	1000	1000
	Number of SCMs					
3	NODESCM	2	6	7	1000	1000
	Number of SCMs					
4	NODESCM	5	9	1000	1000	1000
	Number os SCMs					
5	NODESCM	3	8	10	1000	1000
	Number of SCMs					
6	NODESCM	2	1000	12	1000	1000
	Number of SCMs					
7	NODESCM	10	1	11	13	1000	1000
	Number of SCMs					
8	NODESCM	14	15	16	1000
	Number of SCMs					

TABLE VIII

DISTRIB (DISTRIBUTION) TABLE

SCMs		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	DIST	.070	.070	.110	.110	.007	.007	.007	.035	.035	.060	.020	.020	.090	.119	.119	.1220
2	DIST	.070	.070	.110	.110	.007	.007	.007	.035	.035	.060	.020	.020	.090	.119	.119	.1220
3	DIST	.060	.060	.215	.215	.013	.013	.014	.035	.035	.120	.030	.030	.060	.033	.033	.0340
4	DIST	.060	.060	.215	.215	.013	.013	.014	.035	.035	.120	.030	.030	.060	.033	.033	.0340
5	DIST	.025	.025	.215	.215	.083	.003	.003	.040	.040	.060	.070	.070	.010	.073	.073	.0750
6	DIST	.025	.025	.215	.215	.003	.003	.003	.040	.040	.060	.070	.070	.010	.073	.073	.0750
7	DIST	.025	.025	.215	.215	.003	.003	.003	.040	.040	.060	.070	.070	.010	.073	.073	.0750
8	DIST	.045	.045	.090	.090	.087	.007	.007	.150	.150	.060	.070	.070	.070	.053	.053	.0540
9	DIST	.045	.045	.090	.090	.087	.007	.007	.150	.150	.060	.060	.060	.070	.053	.053	.0540
10	DIST	.030	.030	.190	.190	.010	.010	.010	.035	.035	.180	.030	.030	.060	.053	.053	.0540
11	DIST	.030	.030	.070	.070	.013	.013	.014	.030	.030	.050	.165	.165	.090	.076	.076	.0780
12	DIST	.030	.030	.070	.070	.013	.013	.014	.030	.030	.050	.165	.165	.090	.076	.076	.0780
13	DIST	.075	.075	.125	.125	.003	.003	.003	.035	.035	.110	.080	.080	.120	.043	.043	.0440
14	DIST	.070	.070	.065	.065	.007	.007	.007	.070	.070	.080	.070	.070	.070	.092	.092	.0950
15	DIST	.070	.070	.065	.065	.007	.007	.007	.070	.070	.080	.070	.070	.070	.092	.092	.0950
16	DIST	.070	.070	.065	.065	.007	.007	.007	.070	.070	.080	.070	.070	.070	.092	.092	.0950

TABLE IX

SCM EDIT TABLE

Destination
Nodes

Source SCM	1	2	3	4	5	6	7	8
1	.1400	.2200	.0200	.0700	.0600	.0400	.0900	.3600
2	.1400	.2200	.0200	.0700	.0600	.0400	.0900	.3600
3	.1200	.4300	.0400	.0700	.1200	.0600	.0600	.1000
4	.1200	.4300	.0400	.0700	.1200	.0600	.0600	.1000
5	.0500	.4300	.0100	.0800	.0600	.1400	.0100	.2200
6	.0500	.4300	.0100	.0800	.0600	.1400	.0100	.2200
7	.0500	.4300	.0100	.0800	.0600	.1400	.0100	.2200
8	.0900	.1800	.0200	.3000	.0600	.1200	.0700	.1600
9	.0900	.1800	.0200	.3000	.0600	.1200	.0700	.1600
10	.0600	.3800	.0300	.0700	.1800	.0600	.0600	.1600
11	.0600	.1400	.0400	.0600	.0500	.3300	.0900	.2300
12	.0600	.1400	.0400	.0600	.0500	.3300	.0900	.2300
13	.1500	.2500	.0100	.0700	.1100	.1600	.1200	.1300
14	.1400	.1300	.0200	.1400	.0800	.1400	.0700	.2800
15	.1400	.1300	.0200	.1400	.0600	.1400	.0700	.2800
16	.1400	.1300	.0200	.1400	.0800	.1400	.0700	.2800

Source Node

Destination SCM	1	2	3	4	5	6	7	8
1	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000
2	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000
3	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000
4	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000
5	.3300	.3300	.3300	.3300	.3300	.3300	.3300	.3300
6	.3300	.3300	.3300	.3300	.3300	.3300	.3300	.3300
7	.3400	.3400	.3400	.3400	.3400	.3400	.3400	.3400
8	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000
9	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000
10	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
11	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000
12	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000
13	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
14	.3300	.3300	.3300	.3300	.3300	.3300	.3300	.3300
15	.3300	.3300	.3300	.3300	.3300	.3300	.3300	.3300
16	.3400	.3400	.3400	.3400	.3400	.3400	.3400	.3400

TABLE X

LINKS TABLE

From		To Node		LINKS				
NODE=	1 LINKS	1	0	0	0	0	0	0
NODE=	1 LINKS	2	1	402103	0	0	0	0
NODE=	1 LINKS	3	3	201205	301306	302407	0	0
NODE=	1 LINKS	4	8	0	0	0	0	0
NODE=	1 LINKS	5	0	0	0	0	0	0
NODE=	1 LINKS	6	0	0	0	0	0	0
NODE=	1 LINKS	7	2	101113	102213	0	0	0
NODE=	1 LINKS	8	1	202316	0	0	0	0
NODE=	2 LINKS	1	1	103402	0	0	0	0
NODE=	2 LINKS	2	0	0	0	0	0	0
NODE=	2 LINKS	3	2	303105	204307	0	0	0
NODE=	2 LINKS	4	0	0	0	0	0	0
NODE=	2 LINKS	5	1	304410	0	0	0	0
NODE=	2 LINKS	6	0	0	0	0	0	0
NODE=	2 LINKS	7	0	0	0	0	0	0
NODE=	2 LINKS	8	2	203315	104216	0	0	0
NODE=	3 LINKS	1	3	205201	306301	407302	8	0
NODE=	3 LINKS	2	2	105303	307204	0	0	0
NODE=	3 LINKS	3	0	0	0	0	0	0
NODE=	3 LINKS	4	3	405408	106309	107409	0	0
NODE=	3 LINKS	5	2	206210	207310	0	0	0
NODE=	3 LINKS	6	0	0	0	0	0	0
NODE=	3 LINKS	7	0	0	0	8	0	0
NODE=	3 LINKS	8	2	305314	406215	0	0	0
NODE=	4 LINKS	1	0	0	0	0	0	0
NODE=	4 LINKS	2	0	0	0	0	0	0
NODE=	4 LINKS	3	3	408405	309106	409107	0	0
NODE=	4 LINKS	4	0	0	0	0	0	0
NODE=	4 LINKS	5	1	509110	0	0	0	0
NODE=	4 LINKS	6	2	108111	109112	0	0	0
NODE=	4 LINKS	7	1	208313	0	0	0	0
NODE=	4 LINKS	8	2	308214	209116	0	0	0
NODE=	5 LINKS	1	0	0	0	0	0	0
NODE=	5 LINKS	2	1	410304	0	0	0	0
NODE=	5 LINKS	3	2	210206	310207	0	0	0
NODE=	5 LINKS	4	1	110509	0	0	0	0
NODE=	5 LINKS	5	0	0	0	0	0	0
NODE=	5 LINKS	6	0	0	0	0	0	0
NODE=	5 LINKS	7	0	0	0	0	0	0
NODE=	5 LINKS	8	0	0	0	0	0	0
NODE=	6 LINKS	1	0	0	0	0	0	0
NODE=	6 LINKS	2	0	0	0	0	0	0
NODE=	6 LINKS	3	0	0	0	0	0	0
NODE=	6 LINKS	4	2	111108	112109	0	0	0
NODE=	6 LINKS	5	0	0	0	0	0	0
NODE=	6 LINKS	6	0	0	0	0	0	0
NODE=	6 LINKS	7	1	312413	0	0	0	0
NODE=	6 LINKS	8	2	211114	212115	0	0	0

two and three contain the SCM number to which the trunk is
connected in the owner PSN. Position one identifies which
line it is of that SCM. Positions five and six identify
the SCM to which the transmission trunk is connected and
position four identifies which trunk it is in that SCM.

An LD (Link Distance) table is initialized as des-
cribed in Chapter Three and Figure 4. This is done by
setting the entire table to infinity (or 1000) and then
those positions that have PSN to PSN links to one.

The NC (Node Connectivity) array (as portrayed in
Figure 13) was changed to an eight by eight array containing
the same information with infinity (1000) where no link
exists. This eliminated the need for a P array which is
not included in the simulation.

The final tasks performed in UI are calls to MINHOP
and RTABLE in function UF to complete initialization.
After this a return to the caller of UI initiates the simula-
tion.

FUNCTION UF (USER FUNCTION)

Function UF performs four of the background tasks des-
cribed in Chapter Three. They are MINHOP, UPDATE, RTABLE and
TTABLE. It also assigns the attributes to Q-GERT simulation
transactions. This includes not only those which represent
AUTODIN II packets, but those which flow across the clock
portion of the Q-GERT network. It makes the required branch-

ing decision when a transaction traverses the activity from Q-GERT node eight to Q-GERT node nine. Finally UF supplies the line transmission delay time for transactions simulating AUTODIN II packets flowing to other SCMs in other PSNs.

UF ENTRY. The UF function is called from Q-GERT nodes two and five. It is called from the activity between Q-GERT nodes eight and nine and from the five activities between Q-GERT nodes 11,12,13,14,15 and Q-GERT nodes 16,17, 18,19,20. When UF is called from Q-GERT node two a zero is passed as a parameter. This identifies the call as coming from the clock portion of the Q-GERT network and UF assigns attributes (there are 10 attributes in this simulation's transactions) to the clock transaction. Attributes one and two are assigned constants of 1.0 and 0.0 respectively. Attribute three is supplied by a counter called ICLOCK. ICLOCK is initially zero. Each time UF is called from Q-GERT node two ICLOCK is increment by one. If ICLOCK becomes greater than eight it is reset to one. After this process is accomplished the contents of ICLOCK are assigned to attribute three of the Q-GERT simulation transaction. Since a transaction is generated across the clock network every 12.5 (simulation) milliseconds, every 100 millisecond interval is divided into eight segments. The clock transaction is used to initiate the MESGEN process in subroutine US and provides an FTICK/STICK time interval, as described in Chapter Three, for each Packet Switching Node. Attribute

three selects the PSN which will generate "Bad News/Good News" status messages (Chapter 4, Subroutine US, MESGEN). Keying all nodes every 100 millisecond could cause peaks in network traffic due to the possible release of 56 status packets at the same time. Initiating a separate node every 12.5 milliseconds precludes that from happening.

When UF is called from Q-GERT node five the identification number of the Q-GERT SCM Model network is passed to UF as a parameter. This number corresponds to a particular SCM and is used as the SCM's identification. The number will be between one and twenty-five. Using the SCM number (as an index) and the data arrays established in subroutine UI from user transactions 001 through 004, attributes which describe the simulated AUTODIN II packet can be assigned to the Q-GERT transaction. Attribute one is packet type. The code for attribute one is determined by using a random number obtained from the Q-GERT subroutine DRAND (Ref 8:444) and the SCMs percent of short packets (SHRTPKP). If the packet is a short packet a two is placed in attribute one. If it is a long packet a three is placed in attribute one. A one in attribute one signifies a AUTODIN II system status packet. Status packets are generated in MESGEN.

Attribute two is packet priority. A cumulative array of four values is developed using the SCMs precedence percentages (PRECDNC). A corresponding array of four codes, (10,20,30,40) is also built. These two arrays are passed to

Q-GERT subroutine DPROB (Ref 8:251) which select the packet priority from the codes.

Attribute three identifies the source SCM and is the SCM number. Attribute four is the Destination SCM. Another cumulative array with 25 entries is established using the distribution table (DISTRIB) developed by the matrix operation in UI. A code array containing the numbers 1 to the maximum SCM number is also built. These two arrays are passed to the Q-GERT subroutine DPROB and it selects the destination SCM to be placed in attribute four. If the packet is a long packet, it may be from either the special traffic or the general traffic. A percentage is developed by dividing SPMCHRS by SPMCHRS plus GNMCHRS. If this percentage is greater than a random number between zero and one (obtained from DRAND), attribute ten is assigned a two for special traffic. If the percentage is less than the random number, attribute ten is assigned a one for general traffic.

Attributes five through nine are assigned by foreground task PAKROUT, which is in subroutine UO. PAKROUT is called from subroutine US when a Q-GERT transaction passes between Q-GERT nodes seven and eight.

When UF is called from the activity between Q-GERT nodes eight and nine a parameter containing 101 is passed to UF. This indicates one of three conditions have occurred:

1. The packet's destination has been disconnected and the packet is to be discarded. Also network status packets that have reached their destination and have been processed are sent

here to be discarded.

2.   A status packet is to be delivered to another
     SCM in the same PSN for background processing.

3.   A status or data packet's destination is in
     another node but the packet must enter the line
     output queue of another SCM within the current
     PSN to reach that node.

The conditions were detected during the Q-GERT simulation transaction's traversal of the activity between Q-GERT nodes seven and eight. A call is made to subroutine US, which then calls PAKROUT (in subroutine UO). PAKROUT does the required tests and assigns the values to attributes five, six and eight to cause processing along this activity. The primary condition (see Figure 17) was that attribute five be less than -.10.

Immediately upon entering UF, attribute five is made positive by using the FORTRAN ABS Function. If condition two or three is the reason for entering, attribute five is the next SCM for packet delivery. If attribute six is equal to or less than minus one, condition one holds and the packet is discarded at this SCM in Q-GERT node nine. The requires use of Q-GERT subroutine NFTBU to insuring routing to Q-GERT node nine of this SCM model.

If attribute six is greater than minus one, and attribute one is less than two, the packet is a status packet and either condition two or three holds. The packet, through use of Q-GERT subroutines NODCV (Ref 8:344) and NFTBU, is routed to Q-GERT node six of the SCM model identified in

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attribute five.

If attribute six is greater than minus one, and attribute one is equal to or greater than two, the packet is a data packet and condition three holds. The packet is routed to Q-GERT node eight of the SCM identified in attribute five.

When UF is called from one of the activities between Q-GERT nodes 11,12,13,14,15 and Q-GERT nodes 16,17,18,19,20 a parameter containing 102 is passed to UF. This signifies that a packet will be transmitted across a transmission line. UF returns the contents of attribute nine to the activity. Attribute nine contains the transmission delay time to be used by the activity. The transmission delay time is calculated as follows:

delay time = ((56kilobits/sec ÷ 1000 millisecond/sec)
X number chars/packet) + (trunk miles ÷
100 miles/millisecond)

UPDATE. The simulation subroutine UPDATE (discussed in Chapter Three) consists of MINHOP, RTABLE and TTABLE. If UPDATE is called by MESGEN due to a change in PSN status at this node, all three background tasks are processed. If UPDATE is called due to receipt of a status packet from another node only RTABLE and TTABLE are initiated.

MINHOP. The simulation subroutine MINHOP builds three tables. These are the D table or distance table (Table XI), the HOP table (Table XII) and the LIST table (Table XIII). No function could be found for the LIST table. Therefore the process to build it will not be described.

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TABLE XI

DISTANCE TABLE

To Node	From Node		LINKS 1	2	3	4	5	6
1	1	D	0.00	0.00	0.00	0.00	0.00	0.00
2	1	D	1.00	2.00	1000.00	2.00	1000.00	1000.00
3	1	D	2.00	1.00	1000.00	2.00	1000.00	1000.00
4	1	D	3.00	2.00	2.00	2.00	1000.00	1000.00
5	1	D	2.00	2.00	3.00	3.00	1000.00	1000.00
6	1	D	1000.00	3.00	2.00	2.00	1000.00	1000.00
7	1	D	1000.00	1000.00	1.00	1000.00	1000.00	1000.00
8	1	D	2.00	2.00	1000.00	1.00	1000.00	1000.00
1	2	D	1.00	2.00	1000.00	2.00	1000.00	1000.00
2	2	D	0.00	0.00	0.00	0.00	0.00	0.00
3	2	D	2.00	1.00	2.00	2.00	1000.00	1000.00
4	2	D	3.00	2.00	2.00	2.00	1000.00	1000.00
5	2	D	1000.00	2.00	1.00	1000.00	1000.00	1000.00
6	2	D	1000.00	3.00	1000.00	2.00	1000.00	1000.00
7	2	D	2.00	3.00	1000.00	3.00	1000.00	1000.00
8	2	D	2.00	2.00	1000.00	1.00	1000.00	1000.00
1	3	D	1.00	2.00	1000.00	1000.00	2.00	1000.00
2	3	D	2.00	1.00	1000.00	2.00	2.00	1000.00
3	3	D	0.00	0.00	0.00	0.00	0.00	0.00
4	3	D	1000.00	1000.00	1.00	2.00	2.00	1000.00
5	3	D	1000.00	2.00	2.00	1.00	1000.00	1000.00
6	3	D	1000.00	1000.00	2.00	1000.00	2.00	1000.00
7	3	D	2.00	1000.00	2.00	1000.00	3.00	1000.00
8	3	D	2.00	2.00	2.00	1000.00	1.00	1000.00
1	4	D	2.00	3.00	3.00	2.00	2.00	1000.00
2	4	D	2.00	2.00	1000.00	3.00	2.00	1000.00
3	4	D	1.00	2.00	1000.00	1000.00	2.00	1000.00
4	4	D	0.00	0.00	0.00	0.00	0.00	0.00
5	4	D	2.00	1.00	1000.00	1000.00	1000.00	1000.00
6	4	D	1000.00	1000.00	1.00	2.00	2.00	1000.00
7	4	D	1000.00	1000.00	2.00	1.00	1000.00	1000.00
8	4	D	2.00	1000.00	2.00	1000.00	1.00	1000.00
1	5	D	2.00	2.00	1000.00	1000.00	1000.00	1000.00
2	5	D	1.00	2.00	1000.00	1000.00	1000.00	1000.00
3	5	D	2.00	1.00	2.00	1000.00	1000.00	1000.00
4	5	D	1000.00	2.00	1.00	1000.00	1000.00	1000.00
5	5	D	0.00	0.00	0.00	0.00	0.00	0.00
6	5	D	1000.00	3.00	2.00	1000.00	1000.00	1000.00
7	5	D	1000.00	3.00	2.00	1000.00	1000.00	1000.00
8	5	D	2.00	2.00	2.00	1000.00	1000.00	1000.00
1	6	D	1000.00	2.00	2.00	1000.00	1000.00	1000.00
2	6	D	3.00	3.00	2.00	1000.00	1000.00	1000.00
3	6	D	2.00	3.00	2.00	1000.00	1000.00	1000.00
4	6	D	1.00	2.00	2.00	1000.00	1000.00	1000.00
5	6	D	2.00	1000.00	1000.00	1000.00	1000.00	1000.00
6	6	D	0.00	0.00	0.00	0.00	0.00	0.00
7	6	D	2.00	1.00	1000.00	1000.00	1000.00	1000.00
8	6	D	2.00	1000.00	1.00	1000.00	1000.00	1000.00

TABLE XII

HOP TABLE

NODES

Node	1	2	3	4	5	6	7	8
HOP 1	0.00	1.00	1.00	2.00	2.00	2.00	1.00	1.00
HOP 2	1.00	0.00	1.00	2.00	1.00	2.00	2.00	1.00
HOP 3	1.00	1.00	0.00	1.00	1.00	2.00	2.00	1.00
HOP 4	2.00	2.00	1.00	0.00	1.00	1.00	1.00	1.00
HOP 5	2.00	1.00	1.00	1.00	0.00	2.00	2.00	2.00
HOP 6	2.00	2.00	2.00	1.00	2.00	0.00	1.00	1.00
HOP 7	1.00	2.00	2.00	1.00	2.00	1.00	0.00	2.00
HOP 8	1.00	1.00	1.00	1.00	2.00	1.00	2.00	0.00

TABLE XIII

LIST TABLE

	Node	Node			Identification			
LIST 1	2	3	7	8	1000	1000	1000	1000
LIST 2	1	3	5	8	1000	1000	1000	1000
LIST 3	1	2	4	5	8	1000	1000	1000
LIST 4	3	5	6	7	8	1000	1000	1000
LIST 5	2	3	4	1000	1000	1000	1000	1000
LIST 6	4	7	8	1000	1000	1000	1000	1000
LIST 7	1	4	6	1000	1000	1000	1000	1000
LIST 8	1	2	3	4	6	1000	1000	1000

TABLE XIV

NODE CONNECTIVITY TABLE

	Node	Node			Identification			
NC 1	2	3	7	8	1000	1000	1000	1000
NC 2	1	3	5	8	1000	1000	1000	1000
NC 3	1	2	4	5	8	1000	1000	1000
NC 4	3	5	6	7	8	1000	1000	1000
NC 5	2	3	4	1000	1000	1000	1000	1000
NC 6	4	7	8	1000	1000	1000	1000	1000
NC 7	1	4	6	1000	1000	1000	1000	1000
NC 8	1	2	3	4	6	1000	1000	1000

A call to MINHOP from UI established these tables initially. Entries to the tables are produced from the LD or link distance table and the NC or node connectivity table. The LD table is a matrix with rows identified as source PSN's and columns identified as destination PSNs. If there is a line connecting a source and a destination PSN and that line is not congested, there is a 1.00 in that matrix position. If there is a direct connection, but the line is congested, there is a 1.01 in that matrix position. If there is no direct connection, the matrix position contains 1000. Both the LD and NC tables are produced in UI.

There is an NC table for each PSN. There are as many entry positions for each NC table as there are PSNs. The table contains the identification numbers of the PSN's to which the owner PSN is directly connected, beginning with lowest numbered PSN to the highest numbered PSN in each succeeding entry position. Entry positions not filled have 1000 in them (Table XIV).

There is a D table for every PSN. The D table rows are assigned to PSNs and the columns are assigned to links. Since there can be only one link between the table owner and each PSN, the table has as many columns as exist PSN's.

The D table entries are either minimum hop distances (minimum number of transmissions line traversals needed to travel from the source PSN to the destination PSN), minimum hop distances plus one, or 1000 (signifying this entry is

not to be used). If a destination PSN can be reached in minimum hops or minimum plus one hops on this link, the entry is that number of hops.

There is a HOP table for each PSN. There is one HOP table entry for each PSN. That entry is the minimum hops required to reach that PSN from the owner PSN. If there is no connection, direct or indirect, between the two the entry is 1000.

The Algorithm for building the D and HOP tables is:

1. Place 1000 in every entry in the tables. Place zeros in those entries connecting the owner PSN to itself.

2. Set a link index to one.

3. Select the D and HOP table owner PSN row from the LD table. Examine each column entry of the LD table, using the PSN number as an index. If the entry is 1.00 or 1.01 (positive) place a one in that PSN position in the HOP table and a one in the matrix position indexed by the PSN number for row and link index number for column. Add one to the link index. If the entry is -1.00 or -1.01 or 1000 do not change the entry. Repeat this step until all entries for that LD row are examined. Note that a minus in the LD table means there is a connection normally, but not when the entry is minus (i.e. the link is down).

4. Set a hop count to one. This count indexes the level of hops used as a basis for the remaining search.

5. Examine each link column from table D in turn. If an entry in the link column is equal to the hop count, determine the row index (Destination PSN number). Select each succeeding entry in that PSN's NC table. If the NC entry is a PSN number examine that row position in D table link column in process. If the entry is greater than the hop count replace that entry with the

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hop count plus one. When every link column has been examined add one to hop count and do step five again. Continue this process until no change is made to the table during an examination of all link columns.

6. In each row of the D table find the minimum number. This is the minimum hop. Replace any row entry which is not equal to minimum hop or minimum hop plus one with 1000. Place each row's minimum hop in the corresponding position in the HOP table.

This process is repeated for each PSN to construct all eight D tables and HOP tables.

The reasoning behind this algorithm is that since direct connectivity is known, those PSNs directly connected to a PSN which is directly connected to the owner PSN can be no more than two hops away (they may be only one). Those PSN's directly connected to a PSN two hops away, can be no more than three hops away. Thus the D table is built in layered increments.

RTABLE. RTABLE produces two tables, SROUTE and ROUTE. RTABLE works on a per PSN basis. When RTABLE is called initially from UI, it is called once for each PSN. Subsequent calls occur due to processing within a specific Q-GERT SCM model, which defines the SCM and, therefore, the PSN for which RTABLE will process.

RTABLE uses the LINKS table to determine which lines are in each link from the processing PSN to other PSNs. Recall that a link consists of all lines between two PSNs. The total number of packets in output queues for a single link is accumulated by accessing each line's output queue

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in that link using the Q-GERT function XNINQ (Ref 8:260).
This is then divided by the number of lines in the link to
obtain the average number of packets in output queues for
that link. This is done for each link from the processing
PSN.

With this information and the processing PSN's D and
HOP tables, RTABLE is ready to build tables ROUTE and SROUTE.
Each of these tables has eight entries, one for each PSN.
The SROUTE table is used when a packet's source SCM is in
the PSN processing the packet. ROUTE is used when the PSN
processing the packet is an intermediate node between the
packet's source and destination SCM's.

The algorithm for building SROUTE and ROUTE is:

1. Begin with the PSN index set to one and SROUTE
    and ROUTE entries set to 1000.

2. Examine the D table row indexed by the PSN index
    a column at a time. If the integer portion of
    the link entry is equal to the HOP table entry
    for the same PSN index and is not infinite
    (1000), determine if the link is congested
    (entry has .01 added to it). If it is multi-
    ply the integer portion times 7 and add it to
    the average number of packets queued for the link.
    If the resulting number is less than the corres-
    ponding entry (indexed by the PSN index) in the
    SROUTE table, replace the entry and do the same
    for the entry in the ROUTE table.

3. If the integer portion of the link entry is
    equal to the corresponding HOP entry plus one,
    do the computation outlined in step 2 but add
    seven for the extra hop. If the resulting
    number is less than the corresponding entry
    in SROUTE (and SROUTE only) replace the entry.

4. After all links are examined add one to the PSN
    index and redo steps 2 and 3. Continue until the
    PSN index is larger than the number of PSNs.

The algorithm determines the best links to be used from source PSN to destination PSN and places them in tables ROUTE and SROUTE.

TTABLE. TTABLE builds table TROUTE. Whenever RTABLE is called TTABLE will also be processed. TTABLE also works on a per PSN basis. TROUTE contains the best Switch Control Module and line to the next Packet Switching Node.

There is a TROUTE table for each PSN. Each TROUTE table contains two entries for each link in the PSN. These two entries define which line in the link contains the minimum queue length. The first entry is the SCM which contains the line and the second entry is the line number.

The processing is a straight forward testing of output queue for each line in a link to find the one with the minimum queue. This is done using the Q-GERT function XNINQ. That line and the SCM it is in make up the entries in TROUTE.

SUBROUTINE US (USER SUBROUTINE)

Subroutine US (User Subroutine) is called from three activities in the Q-GERT network. These are the activity between Q-GERT nodes two and three in the clock network, the activity between Q-GERT nodes 25 and 26 in the modification network, and between Q-GERT nodes seven and eight (the processor activity) in the SCM model network. The parameters passed are zero from the clock network, 30 from the modification network and the SCM model copy identification number

(1 to 25) from the SCM model network, to identify the actions
to be taken by Subroutine US.

If the parameter passed is one through twenty-five
attribute two of the simulation transaction is checked. If
the attribute (AUTODIN II packet priority) is above ten a
processor delay time of 5 milliseconds is passed back to the
activity. If the packet priority is ten or less a processor
delay time of 3 milliseconds is passed back to the activity.
Finally, a call is made to PAKROUT (in Subroutine UO) before
control is returned to the activity. PAKROUT determines the
next destination of the packet.

If the parameter passed is 30, attribute four is
either 900 or 910. If it is 900, the simulation transaction
is either a line up or a line down transaction. Attribute
three is the SCM which is connected to one end of the line.
The SCM at the other end of the line is obtained from the
connectivity information supplied in the user type one record.
This requires the use of attribute three and the line number
in attribute two. From this information the PSNs with a
change in line status are determined and the appropriate
LINKS table entry is selected. The line positions in both
SCM's connectivity information fields are turned negativity
if the line is going down or turned positive if the line is
coming up. If attribute one is minus one the line is going
down. If it is plus one the line is coming up.

If attribute four is 910, the simulation transaction

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is a change transaction that changes either GNMCHRS, SPMCHRS, SHRTPKP or the four PRECDNC fields or any combination of those fields. These fields are in attributes five, six, two and seven through ten. If the attribute is zero no change is made. If there is a value it replaces the original value in the appropriate array. The interarrival time is recomputed using the equation stated in the UI section of this chapter based on the new values.

MESGEN. If the parameter passed to US is zero, it came from the clock network and background task MESGEN is to be executed. MESGEN consists of two sections, "BADNEWS" and "GOODNEWS". BADNEWS is processed for each PSN every 100 millisecond. GOODNEWS is processed for each PSN every 400 milliseconds.

BADNEWS checks to see if any links have become congested or have gone down. The row corresponding to the processing PSN is selected from the LD table. Each entry is examined. If an entry is either negative (connected but out of service) or infinite (1000), the next entry is examined. If the entry is positive but not infinite, each line in the corresponding link is examined (using the LINKS table and the connectivity fields from the type 001 user record). If either end of the line (or both ends) is negative, the entry in the LD table is set negative. If the entry is set negative, the corresponding entry in the NC table is set negative.

If the entry is not set negative, it is tested to see

if it indicates congestion. If it does not indicate congestion the number of packets in all line output queues for the corresponding link are added together and divided by the number of lines to obtain average output queue backup. Then all congestion levels for the lines in the link are added together and divided by the number of lines to obtain an average congestion level. If the average queue backup exceeds the average congestion level the entry is set congested.

When all entries have been checked for link-down and for output link congestion, the total number of packets backed up in the SCM input queues (Q-GERT node seven) belonging to the active PSN is compared to the total obtained by adding the saturation level for those SCMs together. If the backup exceeds the accumulated saturation level, all processing PSN LD table entries which are clear are set to congested.

GOODNEWS checks to see if any links have come up or become uncongested. The LD table row corresponding to the active PSN is selected and each entry is examined. If the entry is negative, the corresponding link is examined. If any line in the link has both ends (in the connectivity fields) positive the LD entry is turned positive but marked congested and the corresponding NC entry is set positive. After all entries are examined for link down, each entry is examined for congestion. If an entry indicates congestion,

the number of packets in all line output queues for the corresponding links are added together and divided by the number of lines to obtain an average output queue backup. Then all congestion levels for the lines in the link are added together to obtain an average congestion level for the link. If the average queue backup is less than the average congestion level the LD entry is marked clear (uncongested).

When all entries have been checked, the total number of packets backed up in the SCM input queues belonging to the processing PSN is compared to the total obtained by adding the saturation levels of those SCMs together. If the total input queue backup exceeds the saturation level all processing PSN LD entries which are clear are set congested.

If either BADNEWS or GOODNEWS changes entries in the LD table, UPDATE (in function UF) is called. This call to UPDATE initiates background tasks MINHOP, RTABLE and TTABLE. An LD table change also causes the generation of AUTODIN II status packets to each PSN other than the processing PSN, through Q-GERT node eight of one of the SCMs in the processing PSN.

If no change has been made by GOODNEWS or BADNEWS, UPDATE is still called but only RTABLE and TTABLE are initiated to update SROUTE, ROUTE and TROUTE.

SUBROUTINE UO (USER OUTPUT)

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Subroutine UO consists of a single foreground task, PAKROUT.

PAKROUT. PAKROUT determines which activity branch should be selected out of Q-GERT node eight of the processing SCM.

Attribute three and four of the simulation transaction to be routed contain the source and destination SCMs. From this information the source and destination PSN are determined. The current SCM is placed in attribute eight. If the current node is equal to the destination node attribute six is set to minus one, marking the transaction for local delivery. If attribute one contains a one and attribute four is equal to the current SCM, the transaction is a status packet for this SCM. This causes UPDATE to be called and MINHOP, RTABLE and TTABLE to be initiated. Whether it is a status packet or not, if it is marked for local delivery attribute four is moved to attribute five. If attribute five does not equal the current SCM, it is set negative. Control is returned to the process which called PAKROUT.

If the destination node was not equal to the current node, an output line must be designated in attribute six. If the source node does not equal the current node the ROUTE table for the current node is used for routing. The entry corresponding to the destination node is selected. If the ROUTE table entry is zero the node cannot be reached. Attribute five is set to minus the current SCM, attribute

six is set to minus ten and control is returned to the process which called PAKROUT. The packet will be discarded. If the entry was not zero, find the corresponding link in the current node's LINKS table. The node that link corresponds to is the next node for routing. Find the next SCM by using the TROUTE table, the current node and the next node. If the next SCM is zero, discard the packet by setting attribute five to minus the current SCM, attribute six to minus ten and returning control to the process which called PAKROUT. If the next SCM was not zero the proper transmission delay is placed in attribute nine. If next SCM (outgoing SCM from this PSN) is equal to the current SCM, set attribute five to the current SCM, set attribute six to the TROUTE table line entry corresponding to the next SCM and return control to the process which called PAKROUT. If the next SCM is not equal to the current SCM set attribute five to minus the next SCM, set attribute six to the TROUTE line entry corresponding to next SCM and return control to the process which called PAKROUT.

If the source node does equal the current node the processing is the same as that specified in the last paragraph except that SROUTE is used instead of ROUTE to find the best link route. The ROUTE table allows only minimum hops, whereas the SROUTE table allows both minimum hops and minimum hops plus one.

Summary

.   The use of Q-GERT's duplication capability to provide
many SCM's, and user input records to configure the line
connections provides a convenient means to reconfigure the
simulated network. The ability to vary the AUTODIN II net-
work load and to disconnect and reconnect lines using user
input records, allows testing the network under varying
workload conditions. The extensive use of Q-GERT queue
nodes (six for each SCM), however, causes the AUTODIN
simulation to require extensive computer core memory
(233000 words of CDC CYBER 750 memory) and the simulation
requires at least 500 seconds of CPU time (for the entire
job stream) to generate sufficient data to be useful. This
limits the usability of the model.

CHAPTER 5

METHODS FOR ANALYZING THE SIMULATION RESULTS

Background

The computer program to simulate the AUTODIN II network
in this thesis effort may generate a large quantity of out-
put data. The problem arises as to how to reduce this data
to a form which can be comfortably manipulated and, on the
other hand, can provide a sufficient quantity and quality of
data for a thorough analysis of the AUTODIN II network. The
methods for analyzing the simulation results used by the
authors are presented in this chapter, and illustrated by an
example simulation run in Appendix A.

The Q-GERT modeling and analysis program provides a
summary of the results of each simulation run in the output
listings. For an explanation of this summary information,
the reader should study Pritsker's text (Ref 8).

Within Q-GERT, there exists a unique capability to per-
form a transaction (or packet) trace. A trace provides a
chronological listing of packets' events from their arrival
at a source SCM, to a tandem PSN (if any) and to the final
destination SCM. For each event of a packet (input queue,
processor, output queue, trunk transmission, discard and

delivery), a record is printed (two output lines) with the following data name variables (Ref 8:245):

1. Q-GERT START NODE

2. Q-GERT ENDNODE

3. ACTIVITY NUMBER

4. START TIME (milliseconds)

5. END TIME (milliseconds)

6. ACTIVITY NUMBER

7. MARK TIME (milliseconds)

8. TRANSACTION NUMBER

9. PACKET ATTRIBUTES (10):

    1. Packet type: status packet, short data packet or long data packet.

    2. Priority level: system packet, CATI, CATII, CATIII ot CATIV.

    3. Source SCM

    4. Destination SCM

    5. Departure SCM (SCM from which the packet will depart this node).

    6. Departure line (line or trunk from which the packet will leave the departure SCM to reach the next SCM).

    7. Processor Time

    8. SCM the packet is presently visiting

    9. Time, in milliseconds, for the packet to be loaded into the output line or transmitted to the destination SCM.

    10. Code to identify the packets source workload: General or Specific.

In only a few seconds of the simulation run, the total packet activities may generate thousands of records. The trace records are produced in chronological order, that is, a single packet's activities are not grouped together. Packet activities are interspersed among each other. Manually searching through the trace records, to organize and summarize packet activities would be an enormous task. For example, an 8 PSN, 16 SCM simulation of AUTODIN II, at 20% of network capacity, for 45 seconds, produced over 60,000 records.

To provide output data for an effective and efficient analysis of the AUTODIN II system, a series of three programs, STRIP, SORTMRG and SUMARIZ, were developed to provide a single data file for analysis. This data file was then processed by the Statistical Package for Social Science (SPSS) for analysis. The following sections will give a description of the three data reduction programs and the SPSS analysis program.

STRIP

Only a portion of the trace records, generated for each packet, are necessary to describe the important events of the packet while traversing through the network. STRIP is a FORTRAN program which extracts pertinent trace data to show the historical events of packets from the time they enter a source PSN to the time they leave a destination PSN. A listing of the program is contained in Appendix B.

The output from the Q-GERT simulation model, including the

trace data, is stored on a disk file, TAPE1. STRIP selects records of Q-GERT activities beginning at the following Q-GERT nodes:

1. Q-GERT node 10, the beginning of the activity to discard packets or to send packets to another SCM within the same PSN.

2. Q-GERT nodes 16 through 20, the beginning of the activity to transmit packets to another SCM within another PSN.

3. Q-GERT node 21, the beginning of the activity to deliver packets to a host or terminal.

These records contain sufficient information to describe or compute the pertinent packet events, for example, time spent in the input queues and the output queues.

Records containing information of the AUTODIN II network configuration (input by the user) are also selected to provide a cross reference between PSN and SCM required in the SUMARIZ program. The Q-GERT simulation summary is written on the output listing and the selected records from the trace data are written to the TAPE2 disc file. TAPE1 is returned.

SORTMRG

Although TAPE2 is a significant reduction in quantity of data from TAPE1, the records are not organized in packet groups. The SORTMRG is a CDC library program to sort and merge data files. In this process, TAPE2 is sorted and the resulting output stored on the TAPE3 disk file. A listing of the SORTMRG cards is contained in Appendix B. The records

are sorted first by packet activities and then by MARKTIME
(the time the packet entered the system). TAPE2 is returned.

SUMARIZ

The SUMARIZ program was developed to reduce the packet
activity records (on TAPE3) into a single record per packet
that could easily be interpreted by the Statistical Package
for Social Sciences (SPSS) or other statistical programs. A
source listing of SUMARIZ is given in Appendix B.

SUMARIZ selects all of a packet's activity records,
until the packet is delivered or discarded, and builds a single
record containing:

1. General information about the type of packet and
   the time in the AUTODIN II network.

2. Detailed information about the packet's activities
   within each node of the network.

Fields for all eight PSNs were included in each record (even
though a packet did not visit all eight PSNs), to provide
easy processing by SPSS. The output records are stored on the
TAPE4 disk file. The output records could easily be punched
on cards, written to magnetic tape or placed on a permanent
file, by appropriately routing or copying TAPE4 in the job
control stream. The output records are in chronological
sequence and consist of five lines (or cards). The format
of the output records are given in the User's Manual (Appendix
A). TAPE 3 is returned.

STATISTICAL PACKAGE FOR SOCIAL SCIENCE (SPSS)

SPSS was selected over other statistical analysis packages because of the thorough documentation available to AFIT students and its prior use by the authors of this thesis. Users may prefer to use other statistical packages or to develop their own analysis program. A listing of an example of the SPSS program cards is given in Appendix B. For an explanation of the SPSS cards, the reader should study Ref 9 and 10. In the example listing, only the fields on card 1 are used in a total data analysis. While the fields on cards 2 through 5 require specific selection or editing. These fields (on cards 2 through 5) are provided to collect data for each PSN. However, since a packet visits only a few of the PSNs in the network, the PSNs not visited must be omitted from the analysis of a single PSN. In SPSS this is done by selecting only those PSNs which were actually visited. This is discussed in more detail in the User's Manual (Ref Appendix A).

This chapter briefly described the methods the authors used to reduce the Q-GERT data into a form for use by a computer library statistical analysis package. These methods proved useful to the authors, but users may desire to incorporate their own methods of analyzing the Q-GERT data. More detailed information on the structures of the output files (produced from the Q-GERT simulation, STRIP, SORTMRG and SUMARIZ programs) is provided in the User's Manual (Appendix A).

CHAPTER 6

VALIDATION AND VERIFICATION

Introduction

Before a simulation model is used to gather data on new
situations, validation and verification should be performed.
Validation insures that the model performs to the expecta-
tions of the modelers. Verification establishes that the
model produces results close enough to those obtained from
the process modeled that when the model is applied to scenarios
for which there is no previous experience, the results obtained
will be useful.

Validation of the AUTODIN II model was not difficult.
Verification on the other hand, proved very difficult as
AUTODIN II is not functional and actual results were not
available for comparison. An effort, however, was made to
both validate and verify the model.

Validation

The Q-GERT simulation language provides a trace capa-
bility. This trace capability allows the modeler to follow
a Q-GERT simulation transaction from it's source to it's

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termination. A line of information is printed when a transaction arrives at a Q-GERT node and when it is leaving a node. When a transaction leaves a node the information printed includes the node it is leaving, the destination node it is going to, the time it leaves the node, the time it will arrive at the next node, the number of the activity it is traversing, the time it was last marked (for AUTODIN II, the origination time for the transaction), the transaction identification number, and the values assigned to it's attributes. When the transaction arrives at a node the trace print line includes all the same types of information, except for the identification number of the node it left. This field is replaced by three asterisks, to identify the print line as presenting information concerning an arrival at a node. Table XV presents examples of both types of print lines as they appear in an AUTODIN II simulation trace.

The authors insured that the simulation performed according to expectations by establishing scenarios for the simulation, then by tracing simulated AUTODIN II packets through the simulated AUTODIN II network to insure they traveled the expected routes, with the expected delays, through the network. The scenarios included normal traffic, congested transmission lines, dropped lines, dropped links, and dropped Packet Switching Nodes (PSNs). Several anomalies were discovered and corrected during validation, including lines not dropping properly, excessive arrivals

TABLE XV

Q-GERT TRACE DATA

Start Node	End Node	Start Time	End Time	Activity Number	Mark Time	Trans Number	Attributes				
7-4	8-4	135.45	140.45	832	135.45	10	2.00	20.00	4.00	12.00	-3.00
							2.00	0.00	4.00	20.60	1.00
***	8-5		135.52	826	103.46	1	2.00	20.00	4.00	8.00	5.00
							4.00	0.00	5.00	24.02	1.00
8-5	14-5	135.52	135.52	0	103.46	1	2.00	20.00	4.00	8.00	5.00
							4.00	0.00	5.00	24.02	1.00
***	14-5		135.52	0	103.46	1	2.00	20.00	4.00	8.00	5.00
							4.00	0.00	5.00	24.02	1.00
14-5	19-5	135.52	159.54	822	103.46	1	2.00	20.00	4.00	8.00	5.00
							4.00	0.00	5.00	24.02	1.00
***	8-3		136.09	830	127.82	36	2.00	20.00	3.00	12.00	3.00
							2.00	0.00	3.00	33.08	1.00
8-3	12-3	136.09	136.09	0	127.82	36	2.00	20.00	3.00	12.00	3.00
							2.00	0.00	3.00	33.08	1.00
***	12-3		136.09	0	127.82	36	2.00	20.00	3.00	12.00	3.00
							2.00	0.00	3.00	33.08	1.00
12-3	17-3	136.09	169.17	836	127.82	36	2.00	20.00	3.00	12.00	3.00
							2.00	0.00	3.00	33.08	1.00
***	2		137.50	0	125.00	5	0.00	0.00	0.00	0.00	0.00
							1.00	0.00	4.00	0.00	0.00
2	2	137.50	150.00	0	137.50	5	0.00	0.00	0.00	0.00	0.00

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at the discard Q-GERT termination nodes, and status packets
not performing UPDATE subroutine at their destination node.

The Q-GERT trace capability proved to be a useful tool
during validation.

Verification

Since AUTODIN II is not functional and since the AUTODIN
II configuration is unique, verification using actual data
for comparison was not possible. Since verification against
actual data was not possible, the next option was to use the
data in the thesis by Capt. Whittenton to compare results
from two different simulations of AUTODIN II constructed
from similar base assumptions. Capt. Whittenton used 20%
of the maximum packet traffic capability projected for
AUTODIN II as the normal traffic load for his simulation,
and introduced one second increases (spikes) to 60%, 70%,
80%, and 90% of maximum projected capacity to study their
effect on the network. The AUTODIN II model was configured
to match Capt. Whittenton's model, including traffic load,
and a 70% one second spike was introduced in the model's
traffic. The resulting data is compared to Capt. Whittenton's
data in Figure 18. The vertical scale of the graph is in
milliseconds and represents the average delay time accumu-
lated by AUTODIN II packets during each one second time
period (horizontal axis scale). The time is accumulated
as a transaction enters the network for graphing purposes.
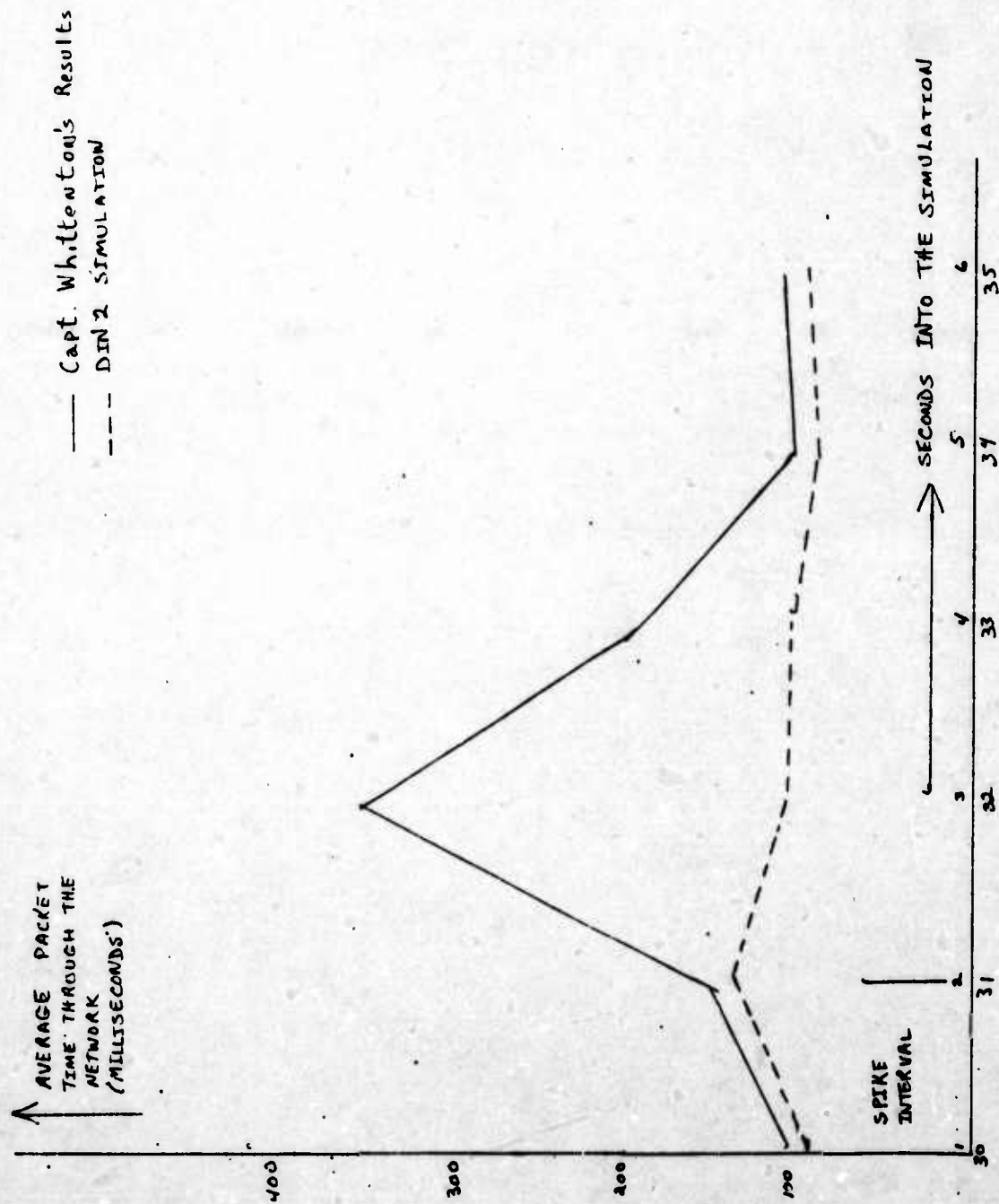
Figure 18 – 70% Spike Comparison

It appears that there is no similarity between the spike in Capt. Whittenton's data (the solid line, Ref 4:F267-271) and the AUTODIN II model data (the dashed line).

The authors examined Capt. Whittenton's thesis, but could not find anything that explained the differences. Capt. Whittenton, during a telephone conversation concerning the possible differences in models, stated that his model generated status packets on a 100 millisecond period basis, whether there was a change in network status or not. The AUTODIN II model only generates status packets when network conditions change. Although Capt. Whittenton's thesis did not confirm his verbal statement, a simple change was made to the AUTODIN II Subroutine US (User Subroutine) to generate status packets on the same periodic basis, rather than on a condition change only basis. Thus, status packets were generated into the network every 100 milliseconds from each Packet Switching Node. This increased traffic by 49 packets each 100 millisecond period. The results were then graphed two ways. First the delay time for each packet was accumulated when the packet entered the network. This produced Figure 19. The path of the dashed line (AUTODIN II results) is clearly much closer to the solid line (Whittenton's results). Since the authors did not know when Whittenton accumulated the delay times, another graph was produced with delay times accumulated when packets left the network. This produced Figure 20, in which the paths of both lines appear
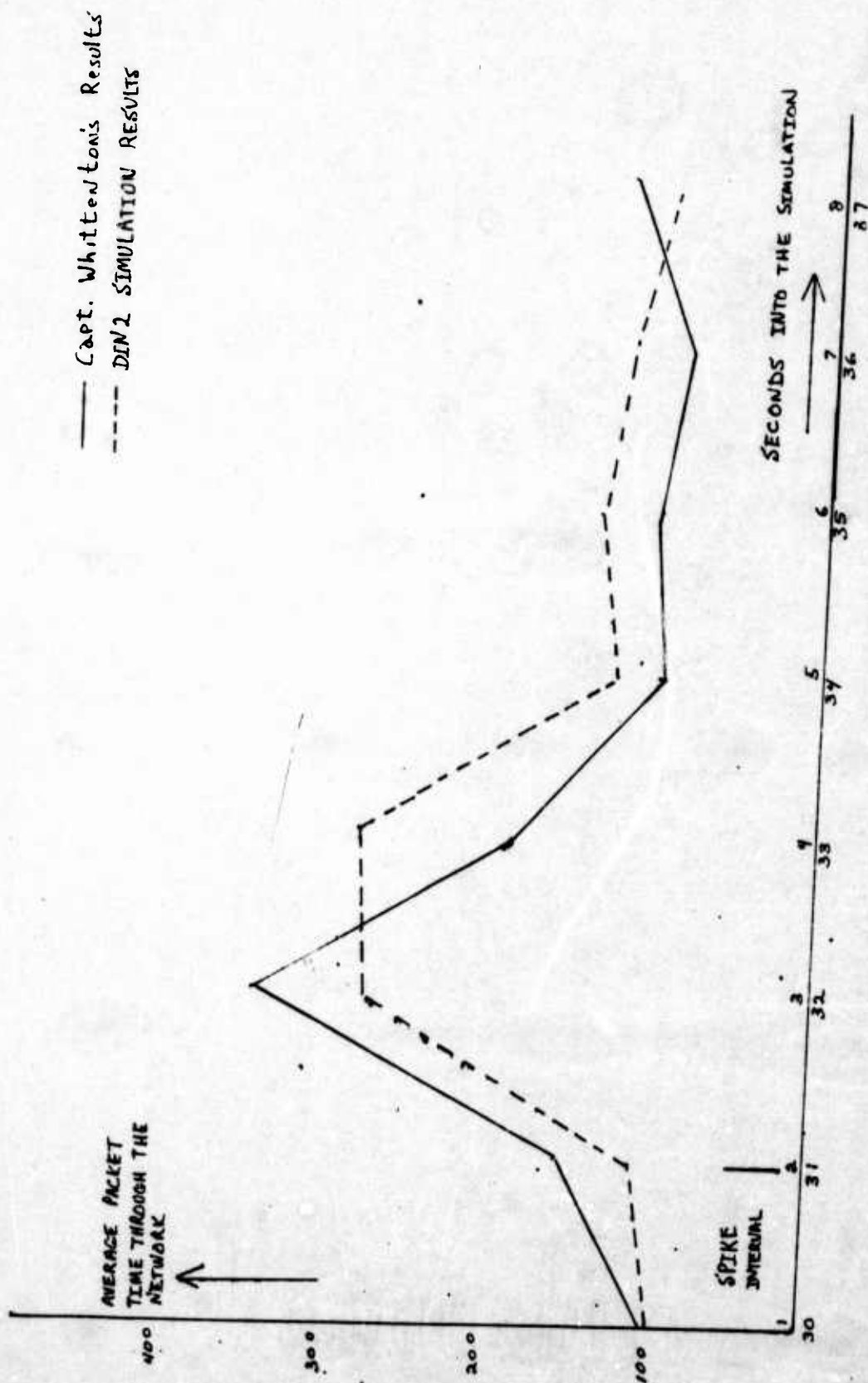
Figure 19 - 70% Spike Comparison With Forced Status Packets

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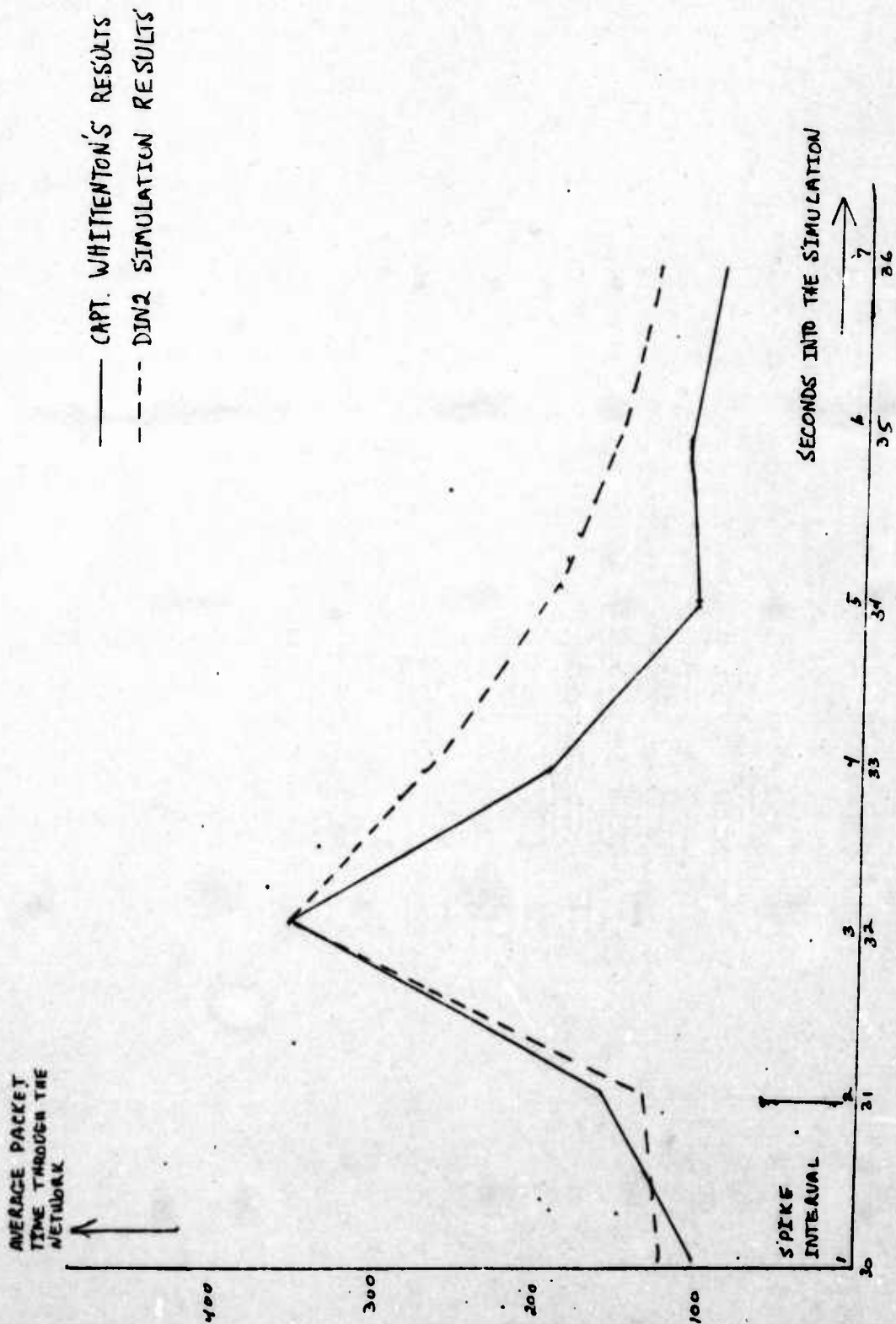
Figure 20 - 70% Spike Comparison as of Packet Termination

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even closer together. The differences between the dashed lines in Figures 19 and 20 are easily explained. In the first of the two graphs, the delays were accumulated as the packets arrival into the network. This would cause both short and long time delays to appear in the same interval, with some intermixing of both, lowering and spreading the spike. In the second graph the delays were accumulated when the packets left the network. Short delays, therefore, would fall close to the packets arrival time in the network, while long delays would appear in more distant intervals, peaking the spike sharply and smoothing the drop off, since the long delays would tend to cluster.

The conclusion drawn from Figure 20 was that there was too much similarity for coincidence and a reasonable assumption was that the two different models produced similar results.

One last area should be discussed for rigor. A simulation run was made with no dynamic changes in the configuration or traffic load of the network to investigate the period of time required for the simulation to stabilize. The mean packet delay times over 1000 millisecond intervals, for 45 such intervals, were visually inspected. There did not appear to be any difference in the variability of any of the intervals. Another inspection of 250 millisecond intervals over 180 periods showed similar results, except at the beginning intervals (this was attributed to "start up" of the

simulation run). A decision was made to use only nine seconds data, eliminating the selection of packets generated in the first 1000 milliseconds, for statistical analysis.

To test the validity of this decision and the visual inspection of the intervals, a statistical multiple comparison test was made on the data (Ref 12:206). The first three interval mean delay times were tested against the remaining total interval mean delay times. This was accomplished by selecting constants, C_i, such that $C_i = 0$. The selected C_i and the corresponding hypothesis test (where u_i is defined to be the expected mean of the ith interval and N is the total intervals, 45) are:

1. $C_1 = -1$, $C_i = 1/(N-1)$ for $i = 2, \cdots, N$
   $H_0 : u_1 = u_1$ where $u_1 = \sum_{i=2}^{N} u_i/(N-1)$

2. $C_1 = 0$, $C_2 = -1$, $C_i = 1/(N-2)$ for $i = 3, \cdots, N$
   $H_0 : u_2 = u_2$ where $u_2 = \sum_{i=3}^{N} u_i/(N-2)$

3. $C_1 = C_2 = 0$; $C_3 = -1$, $C_i = 1/(N-3)$ for $i = 4, \cdots, N$
   $H_0 : u_3 = u_3$ where $u_3 = \sum_{i=4}^{N} u_i/(N-3)$

Each of these hypothesis were tested at the 95% confidence level. Each hypothesis was accepted well within the 95% confidence level. Therefore cimulations at the 20% traffic level may be run with only a 1000 millisecond "warm-up" with a 95% confidence that the mean delay times are stablized.

Computations

95% confidence interval:

$$\sum C_i u_i = \sum C_i x_i = \sqrt{F_{.05}} \, Sp \sqrt{\frac{(r-1)(\ C_i^2)}{n}}$$

$n \approx 130$ n is actually not equal, i.e., this is an approximate test.

$r=45$ # of means

$F_{.05} = 44, \infty = 1.4$

$Sp^2 = 1/r \sum S_i^2 = 7790$

1. $\sum C_i x_i = 108 - 94.4 = 13.6$

   under H_o the $C_i = \pm 1.4(88.3) \sqrt{\frac{44(1.01)}{130}}$

   $= \pm 72.3$

   13.6 is within ± 72.3

2. $\sum C_i x_i = 99.4 - 94.3 = 5.1$

   under H_o the $C_1 = \pm 1.4(88.3) \sqrt{\frac{43(1.01)}{130}}$

   $= \pm 71.4$

   5.1 is within ± 71.4

3. $\sum C_i x_i = 81.8 - 94.6 = -12.8$

   under H_o the $C_i = \pm 1.4(88.3) \sqrt{\frac{42(1.01)}{130}}$

   $= \pm 70.6$

   -12.8 is within ± 70.6

Summary

The AUTODIN II model was both validated and verified.

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The Q-GERT trace mechanism was used to validate that the model performed as planned.

The first option for verification was to compare the simulation results to actual data. Since AUTODIN II was (and is) not yet operational, actual data was not available. The second option was to verify the model against Capt. Whittenton's model. Verification was completed by comparison to the results from Capt. Whittenton's model.

The remaining chapters (7 and 8) will detail analysis of data from the AUTODIN II model.

CHAPTER 7

RESULTS AND ANALYSIS

Introduction

The purpose of this chapter, and Chapter Eight, is to perform an analysis of a potential problem or management concern about the proposed AUTODIN II System.

Before proceeding, the author would like to clarify the following point: the analyses presented in Chapters Seven and Eight do not make full use of all the capabilities which were built into the simulation model. The analyses were performed for specific problems. As mentioned in the first chapter of this thesis, one of the primary goals of this effort was to develop a simulation model for future users. With this objective, the authors developed the model to allow user flexibility in defining the AUTODIN II network configuration and a variety of network up/down conditions, traffic scenarios, message types and workloads. Therefore, the reader should not consider the analysis in this chapter as a restriction or an application of the full capabilities of the simulation model.

The problem for this analysis was derived from a letter to the author from the DCA sponsor, Captain Wade Nielson. The following excerpt from that letter provided the basis for the analysis.

> SCENARIO: The network is operating normally (ie, in a quiescent mode) and something happens to cause an increase in CATI traffic being offered to the network (maybe CATI increases from its nominal of 1% to 3-5% of total network traffic, or higher - use your own judgment).

> DETERMINE: What are the effects on CATII, III and IV traffic? For example, what delays do they experience? What delays do the CATI packets experience? (If CATI traffic does not get delayed much, try increasing the % of CATI traffic). Is the routing algorithm breaking down (you might not be able to tell this with the model you are using)? If your model identifies flow control, are queues building up too high? Is there an increase in network traffic (eg, network status messages, overhead traffic, etc)?

> SCENARIO: Using the above example, what happens if, in the middle of this increase of CATI traffic, some links or nodes fail (get bombed or otherwise destroyed). Now what happens to the rest of the packets? Is it any different than the above scenario?

The author's approach to the above letter is to divide the problem into two parts: the effects of increasing CATI traffic and the effects of node (PSN) failure. Each of these parts is further subdivided into the design of the experiment or simulations and the analysis of the data.

Design of CATI Traffic Increase

From the first scenario above, an analysis of the results of increasing CATI traffic was developed. Although,

The primary concern was the increase of CATI traffic with a normal traffic level, it appeared to the author that the network traffic may have a relationship to the percent of CATI traffic. That is, a significant increase in CATI traffic may be caused by a catastrophic event, say, a war readiness state or build up. This would also cause an increase in the total network traffic. (The effects of the AUTODIN II system, in a war readiness build up or in a state of war, including links and nodes being brought down, is a concern to the sponsor). Therefore, the increased level of CATI messages was tested for various levels of nominal traffic load. The levels of CATI messages and network traffic were chosen by the author for comparative analysis (see Table XVI), and they are not based on any known data source. Each of the second and third levels were step increases from the previous level. The network data used in the simulation was obtained from Western Union Telegraph Company documents (Ref 5 and 11). In the AUTODIN II simulation, by Captain H. Whittenton (Ref 4), a similar data base is used from the same source. The data is described in more detail as an example in the User's Manual (Appendix A), and will not be presented here.

TABLE XVI

PARAMETERS FOR COMPARATIVE ANALYSIS

Network Traffic Levels	Percent of CATI Messages		
Normal Traffic	1%	5%	10%

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30% Increase		1%	5%	10%
50% Increase		1%	5%	10%

Analysis of CATI Traffic Increase

A summary of the simulation output is displayed in Table XVII. Three levels of priority are considered: Priority 1 is assigned to network status packets, priority 2 is assigned to CATI data packets, and priority 3 is assigned to CATII, III and IV data packets. The elements of the table are the average delay times (in milliseconds) of the packets and, in parenthesis, the number of packets in the traffic interval.

TABLE XVII

SIMULATION DATA SUMMARY

Network Traffic	Network Priority	Network CATI Traffic 1%	5%	10%
NORMAL	STATUS			
	CATI		62(6)	125(16)
	CATII,III,IV	103(54)	92(113)	106(114)
30% INCREASE	STATUS			
	CATI		35(6)	91(15)
	CATII,III,IV	97(176)	117(149)	112(173)
50% INCREASE	STATUS			
	CATI		123(12)	79(24)
	CATII,III,IV	103(202)	114(196)	105(165)

An analysis of the network effects of CATI percent levels of traffic was performed on the CATII, III and IV delay times,

because of 1% CATI level did not generate sufficient data for an analysis, and the packet priorities are not statistically independent. With the CATI percent levels iterated for various traffic levels, Table XVII takes the form of a Randomized Complete Blobk (RCB) design (Ref 12:363). The traffic levels are defined as blocks, and the CATI levels as treatments (qr the variable under test). Performing an Analysis of Variance (ANOVA) on the raw data provided the results in Table XVIII.

TABLE XVIII

ANOVA RESULTS

	Sum of Squares	DF	Mean Square	F-Test
Traffic Levels	15,444	2	7,722	.63
CATI Levels	21,910	2	10,955	.89
Interaction	29,897	4	7,474	.65
Explained	68,052	8	8,506	
Residual	11,068,712	907	12,203	

From the F-test values, neither the CATI levels nor the traffic levels were significant (above 80%). Since the CATI packets make up such a small amount of the total packets, it is obvious that the increase to 5% and 10% would not have much effect on packet delay times, unless the network was in a delicate balance or near a saturation level. This statement is backed up by the fact that no network status packets were initiated at any of the nodes, that is, no saturation or con-

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gestion thresholds were exceeded. Since there were no signi-
ficant differences in packet delay times for either the CATI
or traffic levels, the author's conclusion is that the net-
work is capable of handling CATI increases with no significant
change in packet delay times with normal traffic, and with
traffic levels up to 150% of normal.

A follow-up analysis of the above procedure was performed
with another seed. Of specific interest were two CATI means
in Table XVII: the 10% CATI level with normal traffic, and
the 5% CATI level with 50% traffic increase. Both means were
high in comparison with the means of the lower priority
packets. Using another seed, these two means were reduced.
However, the ANOVA for this case depicted similar results of
non significance for the CATI and traffic levels. Due to pro-
gram turnaround times and thesis time constraints, analyses
with 5, or even 10 seconds (rather than one second as used
in the above test), were not performed.

Although no status packets were generated with normal
traffic, the average packet delay time in the output queues
of each node will become important later in this section.
Therefore, for comparison, Table XIX is defined. The first
column contains the quantity of packets entering the node
(either as a source node, tandem node or destination node). The
next column contains the average time spent in the output queue
for each node. Observing the values in Table XIX indicates that
node 1 (Albany PSN) and node 8 (Tinker PSN) may be the first

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congestion problems in a heavy network traffic.

To attempt to ascertain some limits on when the CATI percent levels make a significant difference in packet delays, the above analysis procedure was performed on a simulation with the network traffic level at 40% saturation (or 40% of system capacity), instead of the normal level of 20% saturation. Simulations with higher CATI traffic were also considered. However, the author did not feel that extreme levels of CATI traffic, say 20% to 40%, would effect the packet delay times, and therefore did not simulate higher traffic levels. However, this hypothesis should be simulated and tested before any final conclusions.

TABLE XIX

AVERAGE OUTPUT QUEUE
STATISTICS

	Node	Number of Packets	Time In Milliseconds
1	(Albany)	362	23.6
2	(Andrews)	683	16.2
3	(Fort Dietrick)	172	8.7
4	(Gentile)	363	7.8
5	(Hancock)	226	13.6
6	(McCLELLAN)	313	5.7
7	(Norton)	221	10.5
8	(Tinker)	620	22.2

Table XX displays a summary of the packet delays with a

traffic level of 40% network saturation with associated 30% and 50% increases, and CATI levels of 1%, 5% and 10%.

TABLE XX

SIMULATION DATA SUMMARY

Network Traffic	Network Priority	Percent CATI Traffic		
		1%	5%	10%
40% Saturation	STATUS	80(14)	75(7)	98(28)
	CATI	46(4)	63(18)	95(35)
	CATII,III,IV	150(243)	109(237)	168(234)
30% INCREASE	STATUS			75(42)
	CATI	89(2)	88(19)	112(31)
	CATII,III,IV	145(354)	181(326)	182(343)
50% INCREASE	STATUS	105(49)	88(49)	92(84)
	CATI	35(1)	103(16)	111(42)
	CATII,III,IV	228(404)	213(386)	217(352)

The quantity of network status packets generated in the simulation indicates that the network is periodically becoming saturated.

A comparative analysis between the normal traffic and the 40% saturation traffic simulations was developed. The most interesting comparisons are shown in Table XXI.

TABLE XXI

SIMULATION COMPARISON

	Normal Traffic	40% Saturation Traffic
Qty of Status Packets	0	273

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Average Packet Delay	105	171
CATI Delay	93	99
CATII,III,IV Delay	106	182

The comparisons in Table XXI were significant at or above the 80% level using a Student's T-test of two means and assuming equal variances. The generation of the network status messages increased the system's packet traffic by 8.9%. Note that, although statistically significant, the CATI packets maintained approximately the same delay time. The increased traffic (200%) did not effect the CATI packet delay times very much. However, the low priority packets, CATII,CATIII and CATIV, were significantly effected. The delay times increased by 72%. An ANOVA was performed on the raw data from the 40% saturation traffic simulation with the results shown in Table XXII.

TABLE XXII

ANOVA RESULTS

	Sum of Squares	DF	Mean Square	F-Test
Traffic Levels	1,527,756	2	763,878	21.3
CATI Levels	75,144	2	37,572	1.1
Interaction	407,029	4	101,757	2.8
Explained	1,992,641	8	249,080	
Residual	66,189,634	1850	35,778	

Again, at the 80% confidence level, CATI precent levels

do not make a significant difference in delay times (the F-test of 1.1 is only about 65%). However, the traffic levels are very significant (in the ANOVA of the normal traffic test, traffic levels were not significant). This implies that at 40% saturation, any change in traffic will make a significant change in packet delay times. And as noted above, this change is primarily due to the low priority packets (CATII, CATIII and CATIV). The conclusion can be made that the network has become significantly sensitive to traffic changes at the 40% saturation. The increase in percentage of CATI packets does not make a significant change in total packet delay times (but is approaching a level of significance).

A slight deviation from the sponsor's problem has proven interesting. Table XXIII shows the average output queue statistics for the 40% saturation simulation. Comparison of Tables XIX and XXIII indicate the same problem nodes, that is, node 1 (Albany PSN) and node 8 (Tinker PSN) will probably be the first congested nodes in the network (because of their higher waiting time). However, node 2 (Andrews PSN) was found to be of larger concern; in particular, SCM 3 of that node. Of all status packets generated in the network, 38% came from one Andrews SCM. Table XXIV shows the details of the status packets generated by the network in this simulation. The table is divided into the 40% saturation, the 30% increase (30% increase in traffic above the 40% satura-

tion level) and 50% increase. The elements of the table
are the times (in milliseconds) into the simulation when
the congestion level was found (FTICK or STICK). The times
when the output queues fell below the congestion level are
not shown, but congestion remained for as long as 1500 milli-
seconds at one of the SCMs. SCM 3 of the Andrews PSN was the
first SCM to become congested, and was congested more than
any of the other SCMs.

TABLE XXIII

AVERAGE OUTPUT QUEUE
STATISTICS

	Node	Number of Packets	Time in Milliseconds
1	(Albany)	856	78.3
2	(Andrews)	1434	51.5
3	(Fort Dietrick)	519	21.7
4	(Gentile)	874	34.2
5	(Hancock)	571	54.6
6	(McClellan)	625	14.7
7	(Norton)	527	36.8
8	(Tinkers)	1304	56.6

The SCM at Andrews should be investigated. Captain
John Whittenton, in his thesis (Ref 4:166), stated a problem
in the Andrews-Hancock link and the Albany-Andrews link.
This analysis indicates the problem lies in the same general
location but, specifically in the Andrews SCM. The author

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TABLE XXIV

CONGESTED SCMs IN THE
40% SATURATION RUN

	Albany PSN SCM 1	Andrews PSN SCM 3	Gentile PSN SCM 8	Hancock PSN SCM 10	Tinker PSN SCM 14
40% Saturation		412			
		1612			
30% Increase	6000	3512			3687
	6500	6112			6887
50% Increase	7200	7412	8237	7550	7687
	9000	8412		9950	8687
	9500	9212			9887
		9612			
Total Packets	5	8	1	2	5

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recommends more data be gathered from additional simulation runs and analyzed to verify what appears to be the weakest link in the network. Also, simulations should be run with an additional SCM in the Andrews node, or other possible configuration changes.

Design of PSN Failures

The problem discussed in this portion of Chapter Seven was derived from the second scenario provided in the letter, previously quoted, from Captain Nielson. To develop data for analysis of this problem, the following simulations were designed:

Network Configuration	CATI Level
All PSNs Up	10%
Fort Dietrick PSN Down	10%

The CATI percent was kept at the high of 10%, based on the previous analysis. Fort Dietrick PSN was selected to bring down for the following reasons:

1. Fort Dietrick generates only about 5.1 million characters per hour (3.09 packets per second). This is only 2.2% of the total system traffic. Therefore, bringing Fort Dietrick down would not change the network traffic very much, that is, a "worst case" situation is simulated.

2. The Fort Dietrick PSN contains three SCMs of the sixteen SCMs in the total network. The loss of Fort Dietrick (or Tinker, which also contains 3 SCMs) would cause a greater loss of SCMs than any

of the other PSNs. Note, however, that the loss
of three SCMs may not be as dramatic as the loss
of a PSN with only one SCM which may be of greater
importance in efficiently routing packets to des-
tination PSNs. This analysis may be considered
for a future study.

3. Graphically, Fort Dietrick appears to be the "hub"
of the network (see Figure 3). However, this is
only a perceptive view and may be of little value
if the figure were redrawn.

The Tinker PSN also contains three SCMs. However, the Tinker

PSN was not chosen for the simulated PSN failure because of

its high traffic input (22.8% of the total system traffic).

That is, if the Tinker PSN failed, the network would have

23% less packets.

Analysis of PSN Failures

Two simulations were run for this analysis. The first

simulation was with all PSNs functioning normally, CATI traffic

making up 10% of the total network traffic and a simulation

time of 6500 milliseconds. The second simulation was the same

as the first, except, at 3000 milliseconds into the simula-

tion, the Fort Dietrick PSN was brought down for the remainder

of the simulation. All links of the Fort Dietrick PSN were

down and the input traffic was zero. A study of the raw

data showed that two PSNs (Hancock and Tinker), each at their

own FTICK time (check for bad news), discovered the Fort

Dietrick PSN down and sent information status packets to the

other PSNs. The packets left in the network (and all future

packets) that were destined for the Fort Dietrick PSN, were

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discarded.

Table XXV shows a comparison of the packet delay times between the completely connected network and the network with the Fort Dietrick PSN down. The entries of the table are the average delay times (in milliseconds) of all packets and, in parentheses, the number of packets in the traffic interval. The packets are further broken down into CATI Packets and CATII, III, IV Packets (status packets generated when node 3 went down are not shown). The elements of the table are the average time delays (in milliseconds) and the values in parentheses are the quantity of packets for each case. Node 3 Down (column 1 in Table XXV) statistics exclude the data prior to the PSN going down. A statistical T-test for comparison between two means (assuming equal variances) was performed for each row of Table XXV. The tests showed a significant difference between the two simulations for row 1 (all packets) and row 3 (CATII,III and IV packets) at the 90% confidence level. One of the reasons the CATI packets T-test statistic was smaller than the other row comparisons is due to lower sample sizes. The CATI packets, between the two simulation runs, die show significance at the 77% confidence level.

TABLE XXV

SIMULATION DATA SUMMARY

All Nodes Up   Node 3 (Fort Dietrick) Down

All Packets	96(713)	106(552)
CATI Packets	87(72)	97(61)
CATII,III,IV Packets	97(641)	110(477)

In conclusion, bringing down the "worst case" node, as observed by the author of this chapter, caused a significant increase in packet delay times. However, the increase in packet delay times are small enough that the DCA specifications are not exceeded (Ref 6:43). Therefore, the network can be considered as functioning at an acceptable level. The major loss, in the network, is not in the increased packet delay times, but in the loss of messages originating at, and destined to, the downed node (the Fort Dietrick PSN in the above simulation).

Summary

This chapter has attempted to answer some of the problems of concern to DCA. The approach to the problems was two fold. First, design network simulations with various traffic priorities and configuration changes. Second, statistically analyze and compare the results.

For the traffic priorities, various levels of CATI traffic were simulated and, under normal network traffic, there was no significant difference in packet delay times. When the traffic level was increased to 40% saturation, CATI traffic increases made a significant increase in packet

delay times. However, the delay times were within the DCA specifications. In analyzing the simulation data, it was observed that one of the SCMs in the Andrews PSN was continuously becoming congested before any of the other PSNs. If the AUTODIN II network traffic is projected to increase (specifically, the traffic through the Albany PSN), then the Albany PSN may be a major bottleneck in the network. Further analysis was recommended.

To analyze the effects of network configuration changes or failures, two simulations were run. The first simulation contained normal traffic levels with all PSNs connected. For the second simulation, the Fort Dietrick PSN was brought down during the simulation run. The two simulations were compared and, although a significant difference in delay times was observed, the network was functioning at an acceptable level. That is, the packet delay times were within the DCA specifications.

CHAPTER 8

RESULTS OF NETWORK LOADING

Basis For Analysis

The projected normal loading for the AUTODIN II is
20% of total network capacity. The analysis in Chapter 7
demonstrates that at that loading and up to 200% of that
loading (or 40% of network capacity), the AUTODIN II net-
work operates will within required time constraints. How-
ever, the acquisition delays encountered in past system
purchases have resulted in load capacities exceeding ex-
pectations by wide margins when systems were finally in
place. Therefore the analysis in this chapter will explore
the effects of workloads which are 60, 70, and 80% of total
network capacity.

One area that will be investigated is similar to a
portion of the analysis in Chapter 7. The scenario is:
assume NORAD has detected the possibility of a missile
attack. We postulate that the network would experience a
surge of high priority traffic originating from one site.
Impose this postulation on a network already loaded to 70%
of system capacity. Are the effects significant enough to

cause excessive delays for this or other traffic in the network?

Another aspect that will be explored is the effect of increasing normal workload from 60 to 70 to 80%. Figures 18, 19, and 20 in Chapter 6 demonstrated that transmitting status packets on a periodic basis can sharply increase the sensitivity of the network to changes in traffic. Does increasing workload levels cause status packet generation to approach periodic generation? Also, how does increasing network load effect transmission times of Category I and lower priority packets? These questions will be answered within the text of this chapter.

NORAD Scenario

The NORAD scenario was implemented by designating all traffic from Switch Control Module 16 as special traffic with a priority of Category I. This increased Category I traffic in the network from 1.1% of all data packets to 7.1% of all data packets. This constitutes an increase of 645% in Category I data packets. Figures 21,22, and 23 present graphs of the effects of the increase on transmission times for Category I data packets, Category II data packets, and status packets. The solid line in each graph is the average transmission time (portrayed at each 250 millisecond interval) when the network is loaded with 7.1% priority packets and the dashed line is when the network is loaded with 1.1%
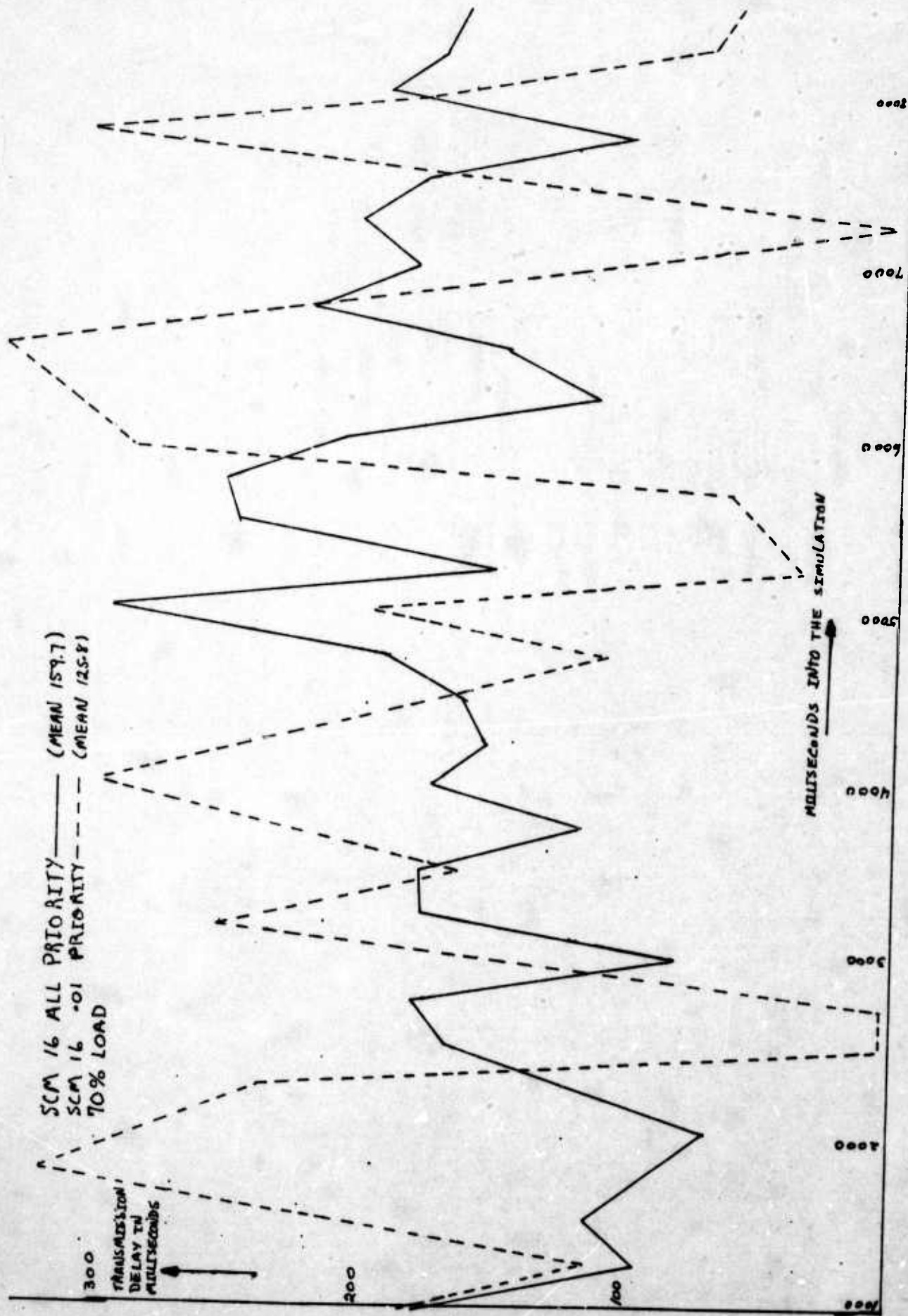
Figure 21 - 7.1% CATI - Effect on CATI

Figure 22 - 7.1% CATII - Effect on CATII
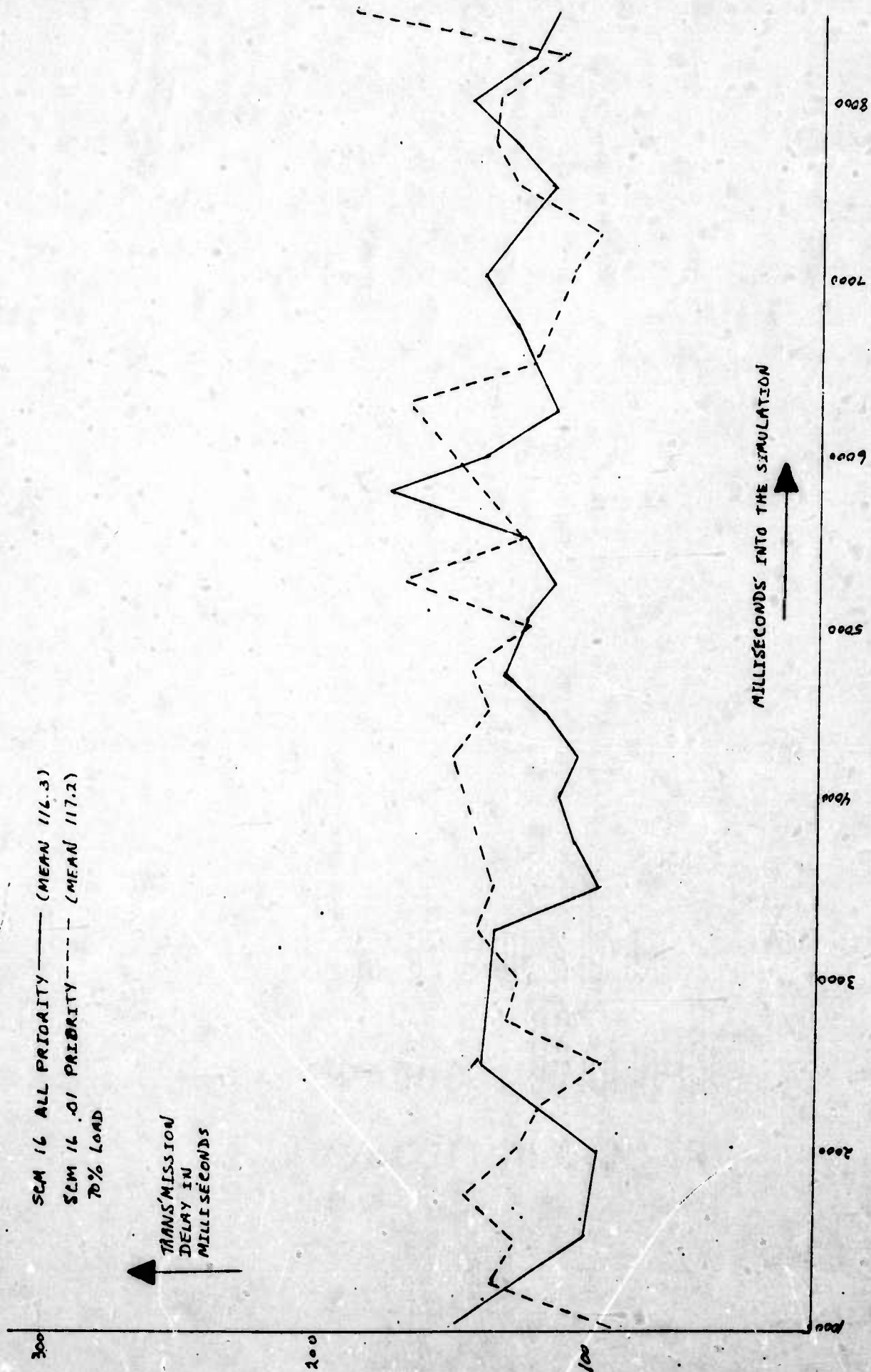
Figure 23 - 7.1% CATT - Effect on Status Packets

priority packets.

The transmission time for each packet was accumulated at the packet's arrival time in the network for graphing purposes. Since the simulation was stopped at 10000 milliseconds (10 seconds) and those packets still in the network were discarded, this caused a sharp drop off in transmission time statistics near the termination of the simulation. Therefore the last 1500 milliseconds of the simulation data is not representative and is not graphed in the figures. For this reason future users may prefer to accumulate transmission times as packets leave the network. This will require a simple change in the SPSS control cards (setting the parameter TIME equal to TIME + TTIME).

A student T-test was performed on the means of each set of graphed data with the null hypothesis that they were equal. This hypothesis was not rejected at the 90% confidence level for Category II packets, although intuitively a reasonable conclusion would be that increasing higher priority workload would increase transmission delays for lower priority workload. The hypothesis was rejected for Category I packets. A visual comparison of the means of the Category I packets shows a 27% increase in transmission time.

Though 93% of the traffic showed no significant change in transmission times, there did appear to be significant changes in flow patterns. Table XXVI lists the mean times

packets spent in queues at each node. The column containing the mean time spent in output queues demonstrates that flows have changed. Four means went up from the 1.1% pri column to the 7.1% pri column, and four means went down. A student T-test was performed on each pair of output queue means. Six of the eight tests rejected the null hypothesis that the means were equal at the 98% confidence level. One of the remaining two rejected the null hypothesis at the 95% confidence level and the other one (Andrews) showed no significant change. Therefore a reasonable assumption is that flow patterns did indeed change.

TABLE XXVI

MEAN TIMES PER PSN

Node	Mean Times In					
	Input Queues		Output Queues		Transmission	
	1.1% Pri	7.1% Pri	1.1% Pri	7.1% Pri	1.1% Pri	7.1% Pri
Albany	1.366	2.695	112.517	137.986	34.07	36.67
Andrews	2.582	2.565	94.740	93.997	23.212	23.479
Fort Dietrick	6.448	5.852	44.228	53.793	51.569	54.322
Gentile	3.797	3.357	117.588	91.595	40.839	36.668
Hancock	1.276	1.234	83.601	49.439	27.634	27.042
McClellan	.812	1.034	21.846	34.118	25.634	27.536
Norton	1.248	1.103	64.470	100.912	42.000	40.336
Tinker	2.071	1.823	245.341	220.827	40.852	38.154

Since the queueing discipline in AUTODIN II is based on

priority, with first-in first-out within priority a reasonable assumption is that significant increases in priority load on the network will increase the queue waiting, and therefore time in the network, for lower priority workload. Since this did not happen, and since there were significant changes in flow patterns through the network, a conclusion is suggested. That conclusion is that the routing algorithm is reacting to network traffic flow conditions and, furthermore, it is reacting in a positive manner.

Normal Traffic Load Increases

The analysis in Chapter 7 examined the network when it was loaded at 20% of network capacity and when it was loaded at 40% of network capacity. This section will examine the network when it is loaded at 60%, 70%, and 80% of network capacity.

No status packets are generated at 20% loading. In other words, no Switch Control Module output lines became congested, nor did any input queues become saturated. The routing algorithm operates as though it were a fixed routing algorithm. However at 40% loading 273 status packets moved in a nine second period and the algorithm no longer acted as though it were a fixed routing algorithm. As the load was increased the status packets generated also increased, as displayed in Table XXVII.

TABLE XXVII

STATUS PACKET FLOW

% of Capacity	Number of Status Packets	% Increase
20%	0	-----
40%	273	-----
60%	403	48%
70%	464	15%
80%	551	19%

But even with these increases in status packets, the generation of status packets for network changes only does not approach the generation of status packets on a 100 millisecond periodic basis. The status packet figures in Table XXVII are for a nine second period. The periodic generation of status packets during that same period would place 4,410 status packets on the network. This is almost ten times the flow of status packets at an 80% load level. In fact, the simulation only generated 4,523 data packets at an 80% load level. This would indicate that periodic generation of status packets either should not be included in the algorithm, or that the period between generations should be considerably longer than 100 milliseconds.

The graph in Figure 24 presents the effects of increasing workload on status packet delays. This graph does not display significant difference to the eye, but a student T-test was used to compare the 60% and 80% means to the 70% mean,
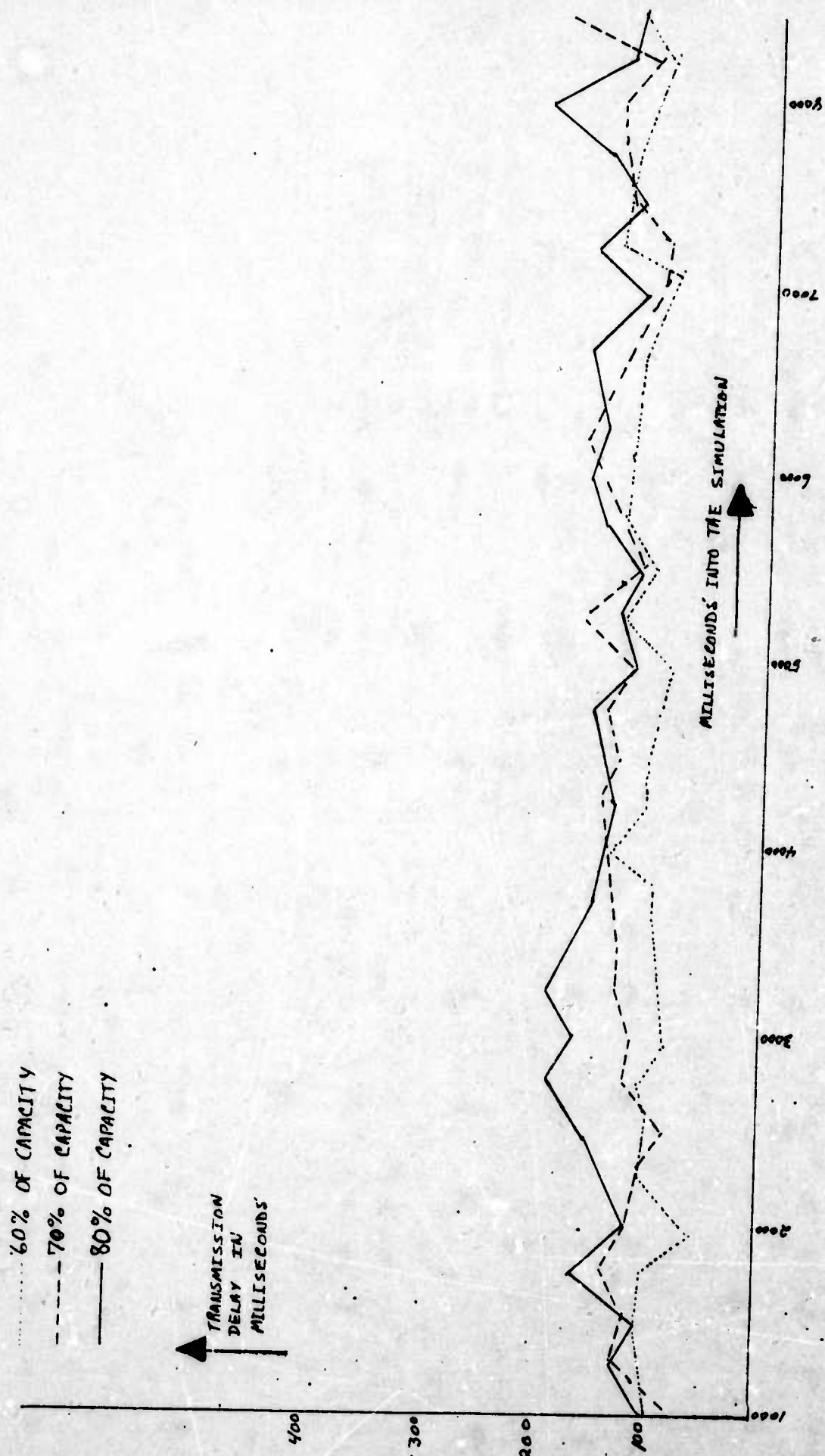
Figure 24 - Network Status Packet Flow Graph

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with a null hypothesis that the differences between them were statistically insignificant. The T-test rejected the null hypothesis at a 98% confidence level. Therefore there are significant differences between the delay times for status packets at different loading percents.

The same is not true for Category I data packets. Though the graph in Figure 25 seems to show more differences than the graph for status packets, the student T-test would not reject the null hypothesis that their means were equal at any confidence level (in the T distribution table, anyway). The increases in network load did not appear to effect Category I transmission times. This may be due to the small percentage of total traffic which Category I packets represents.

The effect of the increases in traffic load on Category II traffic is clearly evidenced by the graph in Figure 26, and the student T-test confirmed that there was significant differences between the means of Category II packet transmission time delays at 60%, 70% and 80% network capacity loadings. Furthermore, the 80% simulation test may not have reached a stable condition during the 10000 millisecond run. The peaks toward the end of the graph were pushing beyond earlier peaks. The drop off caused by accumulating network time at the packet's arrival is clearly evidenced in the behavior of the 80% line.

The Q-GERT simulation data provides more evidence that
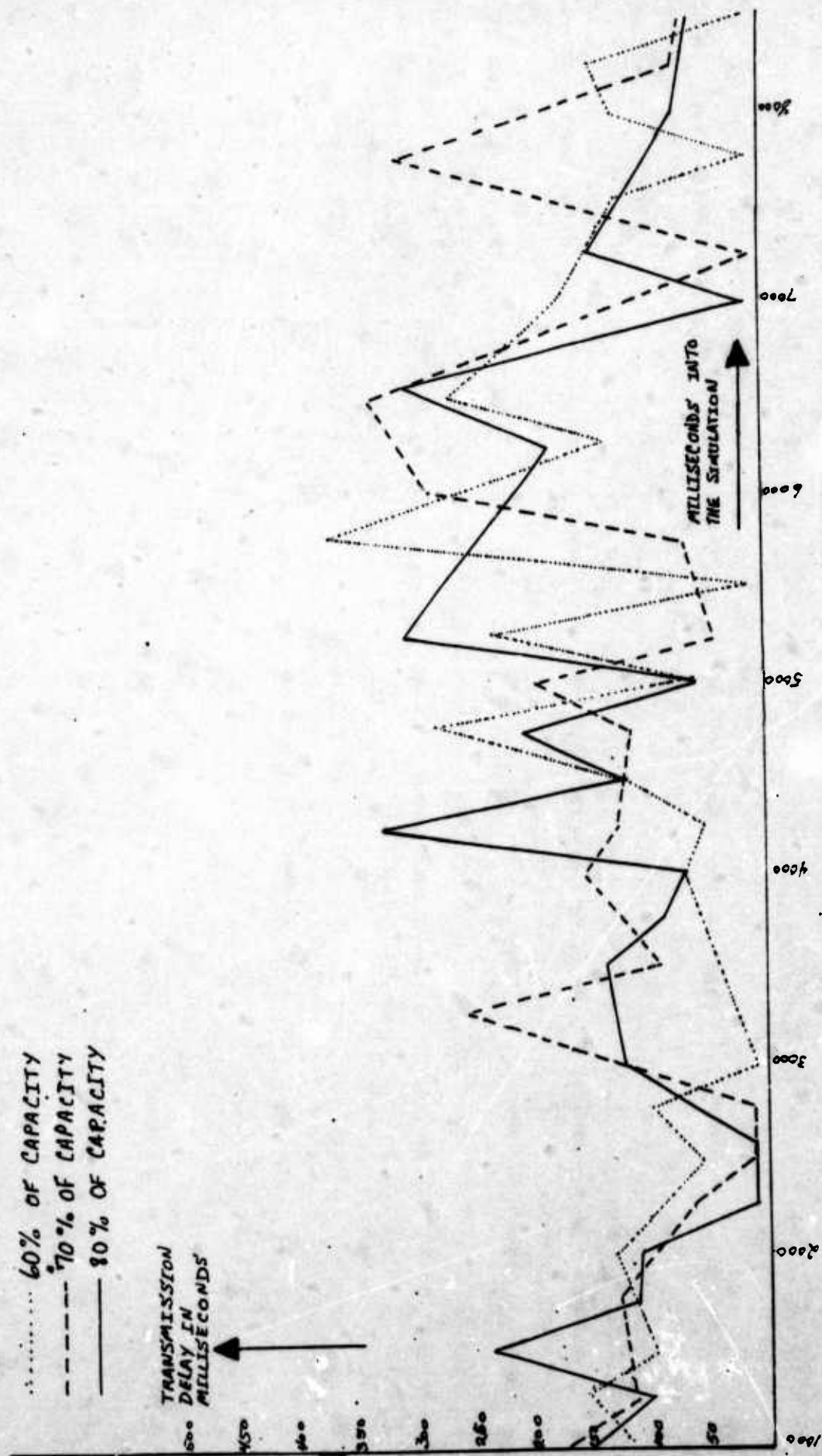
Figure 25 - Category I Flow Graph
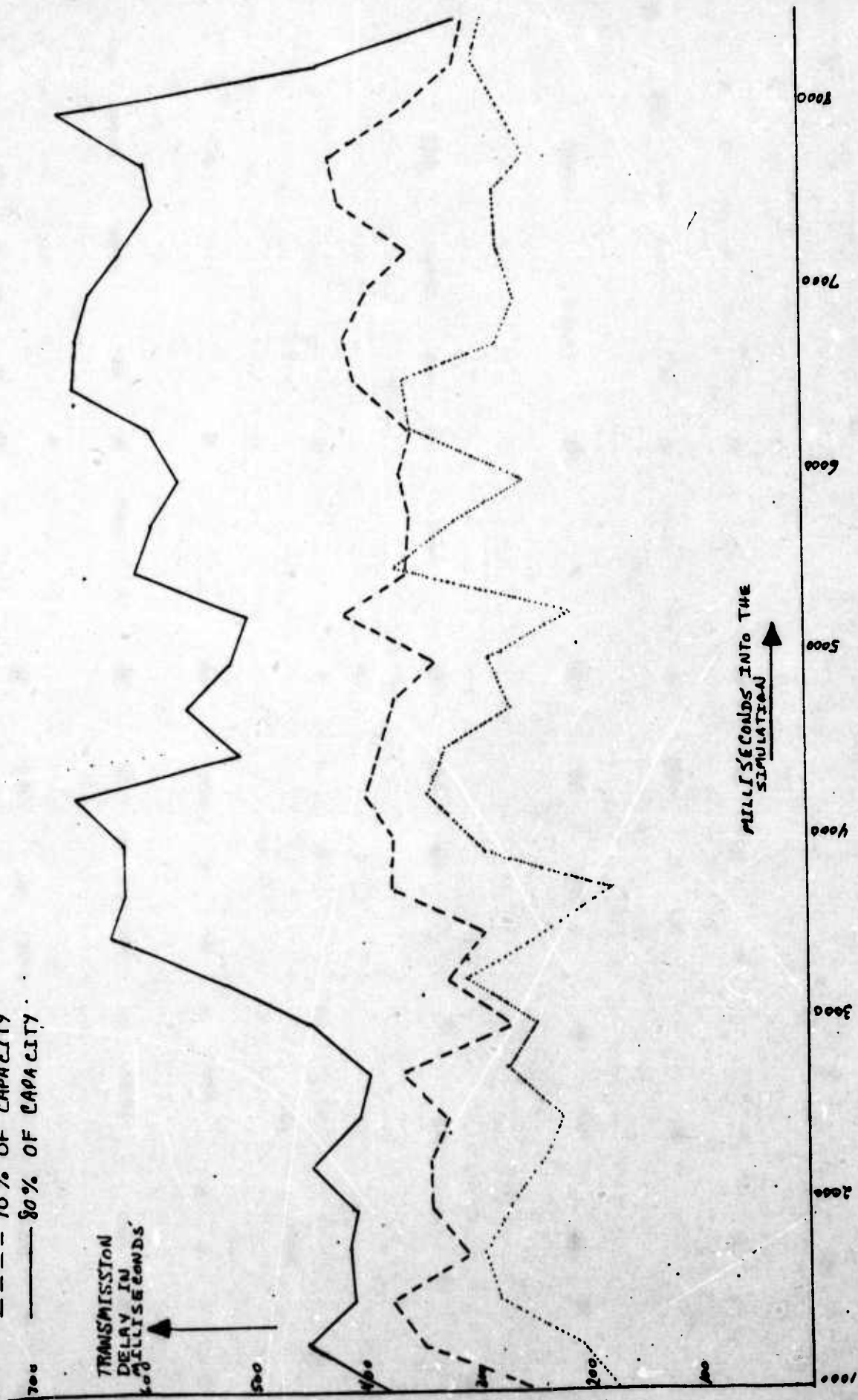
Figure 26 - Category II Flow Graph

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the 80% run may not have stabilized. Many of the Q-nodes representing output queues were either the same as, or close to, the maximum number in that queue when the simulation ceased. This indicates a possible build up in those queues. Also, server utilization was quite high (again from Q-GERT data) with many servers above 90%.

The Q-GERT data for the 70% simulation had much lower queue occupancy figures, although several servers were above 90% utilized, and the 60% simulation had very little average back up.

Conclusions

Periodic generation of status packets should not be a part of the AUTODIN II routing algorithm. Further, loading the network beyond 70% could cause queue back up problems. However, moderate increases in Category I traffic do not seem to effect the network.

By changing the Q-GERT control cards the network could be initialized to the termination conditions of the 80% simulation and the simulation rerun to determine when and with what queue occupancy conditions the simulation stabilizes. This is a possible future experiment requirement. There are also many other possibilities, such as adding and/ or subtracting Switch Control Modules to/from Packet Switching Nodes, changing the line connections between Switch

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Control Modules, and increasing the line connections be-
tween Switch Control Modules.

The analysis of data in Chapters 7 and 8 is only a
small sample of possible uses of the model. Future users
should be limited only by their own imaginations and
sponsors requirements or questions.

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APPENDIX A:

AUTODIN II USER'S MANUAL

Contents

List of Figures

List of Tables

USERS MANUAL

CHAPTER A-1

CONFIGURING THE AUTODIN II
SIMULATION MODEL

Introduction

The AUTODIN II simulation model provides a means for
testing conditions which may not normally exist, but which
could occur, against different network configurations to
find the network configuration which is most responsive.
Thus network configurations and conditions can be tested
before hardware is modified. However, a body of basic
knowledge is required concerning the network to be modeled
in order to configure and exercise the model. Chapter One
will trace an example from conception of the network to
the point of providing the necessary formatted information
to the AUTODIN II simulation. Chapter Two will provide the
formatted input data definition. Chapter Three will describe
information which the model will provide as output. The
necessary job and task control parameters required to com-
plete a computer run will be described in Chapter Four.

The information required from the user to configure and

exercise the model falls naturally into three areas. The first of these areas is information about the physical configuration of the network to be modeled. The second area is information describing traffic load expected over the network. The final area is information concerning traffic control parameters. A section of this chapter will be devoted to each of these areas. Some of this information is static and remains constant throughout a single computer run. Other portions of the information can be changed dynamically during the computer run to simulate changes in traffic load, loss of transmission lines, loss of AUTODIN II nodes, and other occurrences which can happen dynamically. A section concerning information which can be changed dynamically will close this chapter.

Model Configuration

The example which will be used to demonstrate the information necessary to the AUTODIN II simulation model is the eight node AUTODIN II network proposed by Defense Communication Agency (DCA). The maximum number of nodes for the AUTODIN II simulation model is eight, although less nodes can be modeled.

The first concern of the simulation user is the number of network nodes to be simulated. Assume that the model designer has decided to model eight nodes (Figure A-1), located at Albany, Andrews, Hancock, Fort Dietrick, Gentile;
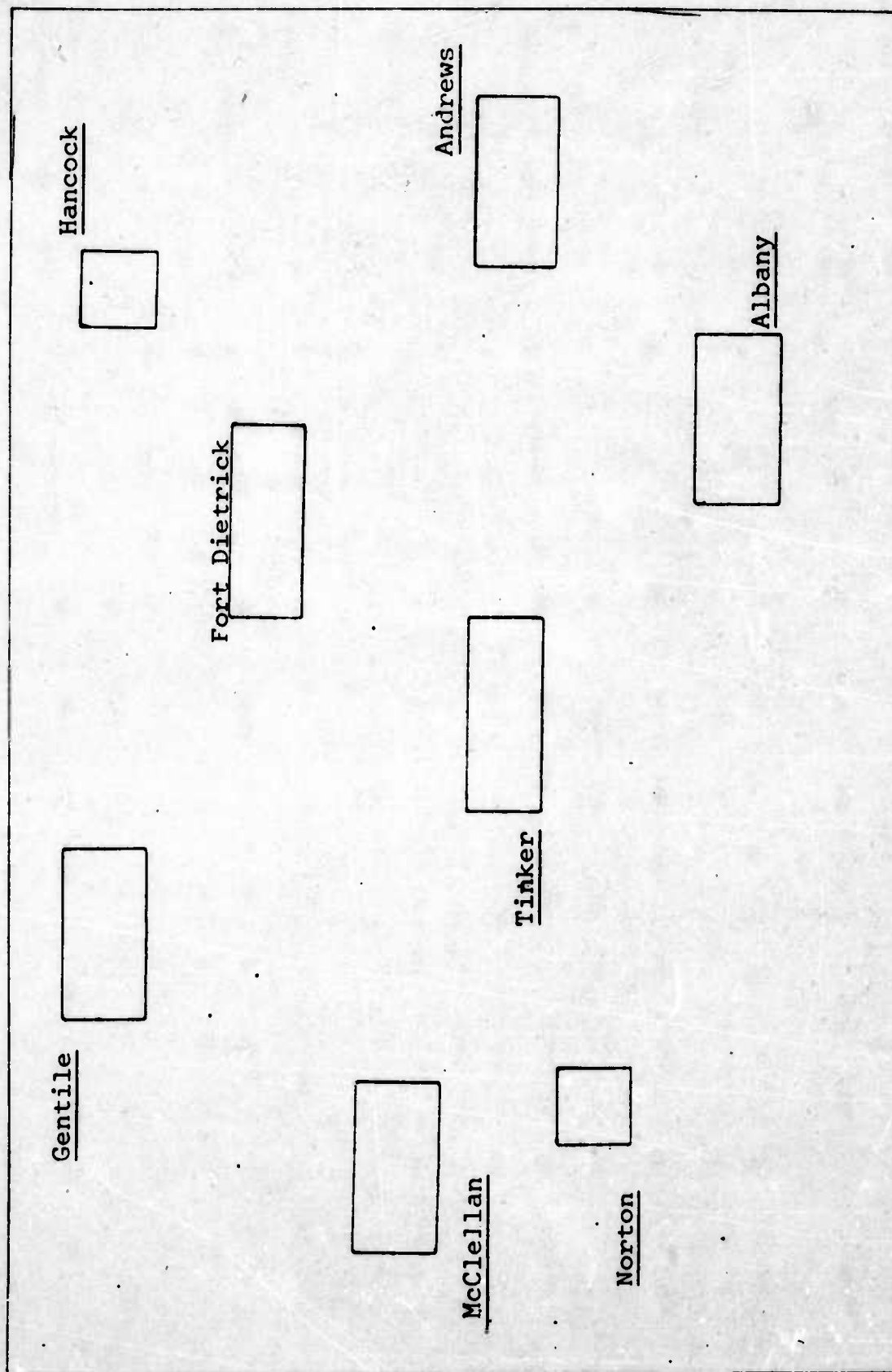
Figure A-1. Selected Packet Switching Nodes

Tinker, McClellan, and Norton. The nodes must then be numbered consecutively from one to the maximum number of nodes modeled (Figure A-2). These numbers will be placed in the user input record field labeled INODE.

Each Packet Switching Node (PSN) is composed of one or more PDP 11/70 computers which perform the process of routing AUTODIN II packets through the network. These computers are called Switch Control Modules (SCMs). The simulation limit is twenty-five (or less) SCMs for the entire network, and five SCMs in each Packet Switching Node. Again assume the model designer, in establishing the information to configure the network, has determined the number of SCMs he wants at each node. To determine this he has considered the traffic load, both coming into the network at that node, and flowing to and through that node from other nodes. More SCMs allow more transmission line connections and more traffic, but, of course, there is a cost constraint. The example decisions are in Table A-I.

TABLE A-I

SWITCH CONTROL MODULES/PSN

City	Packet Switching Node Number	Number of Switch Control Modules
Albany	1	2
Andrews	2	2
Fort Dietrick	3	3
Gentile	4	2
Hancock	5	1
McClellan	6	2
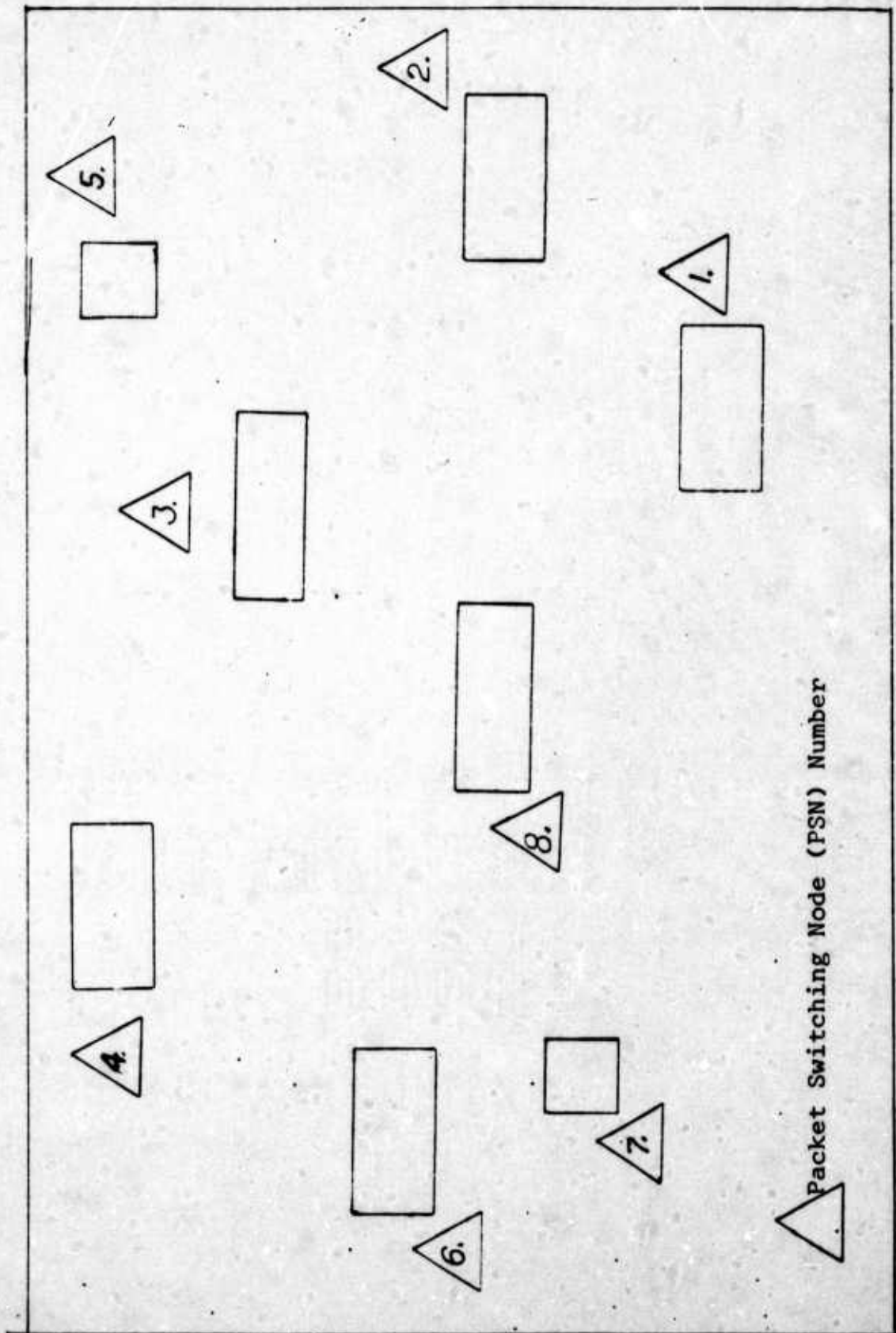
Figure A-2. Packet Switching Node Numbering

$\triangle$ Packet Switching Node (PSN) Number

| Norton | 7 |] |
| Tinker | 8 | 3 |

     Total Switch Control Modules   16

     The Switch Control Modules must be numbered consecutively
within the total network. Therefore the Switch Control
Modules for the example will range from one to sixteen
(Figure A-3). The numbering can be arbitrary as long as
consecutive numbers are used. These numbers will be placed
in the user input record field labeled ISCM when the
record is established. The ISCM and INODE fields appear in
all user input records. All records contain information
at the Switch Control Module level. Therefore the Packet
Switching. Node Number will be repeated for each Switch Con-
trol Module which is contained in it.

     Each SCM is connected to other SCMs by transmission lines.
The simulation limits are from one to five transmission lines
per SCM. Therefore the line limit for the network is 125
(or less). The model designer must determine how SCMs
should be connected together by transmission lines. A
definition is appropriate here. "Trunk" and "line" are
used interchangeably for purposes of this simulation and a
line is a single connection (two way) between two Switch
Control Modules. A link consists of all lines (or trunks)
connecting two Packet Switching Nodes. Figure A-4 illustrates
the line connections for our example. Line connectivity
is established by entries into the ICONSCM fields of user
input record type 001. There are five of these fields,
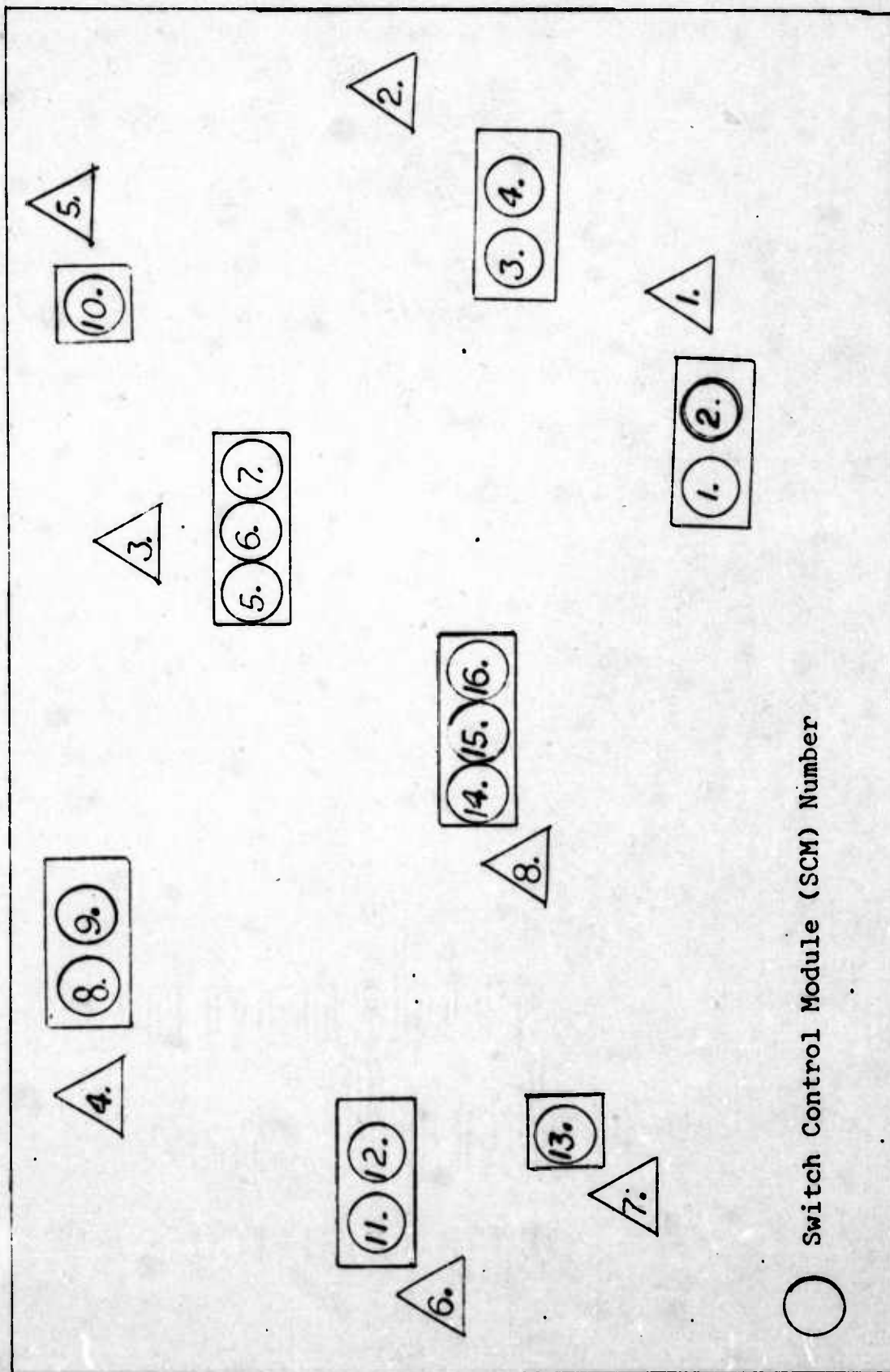
Figure A-3. Switch Control Module Numbering

◯ Switch Control Module (SCM) Number
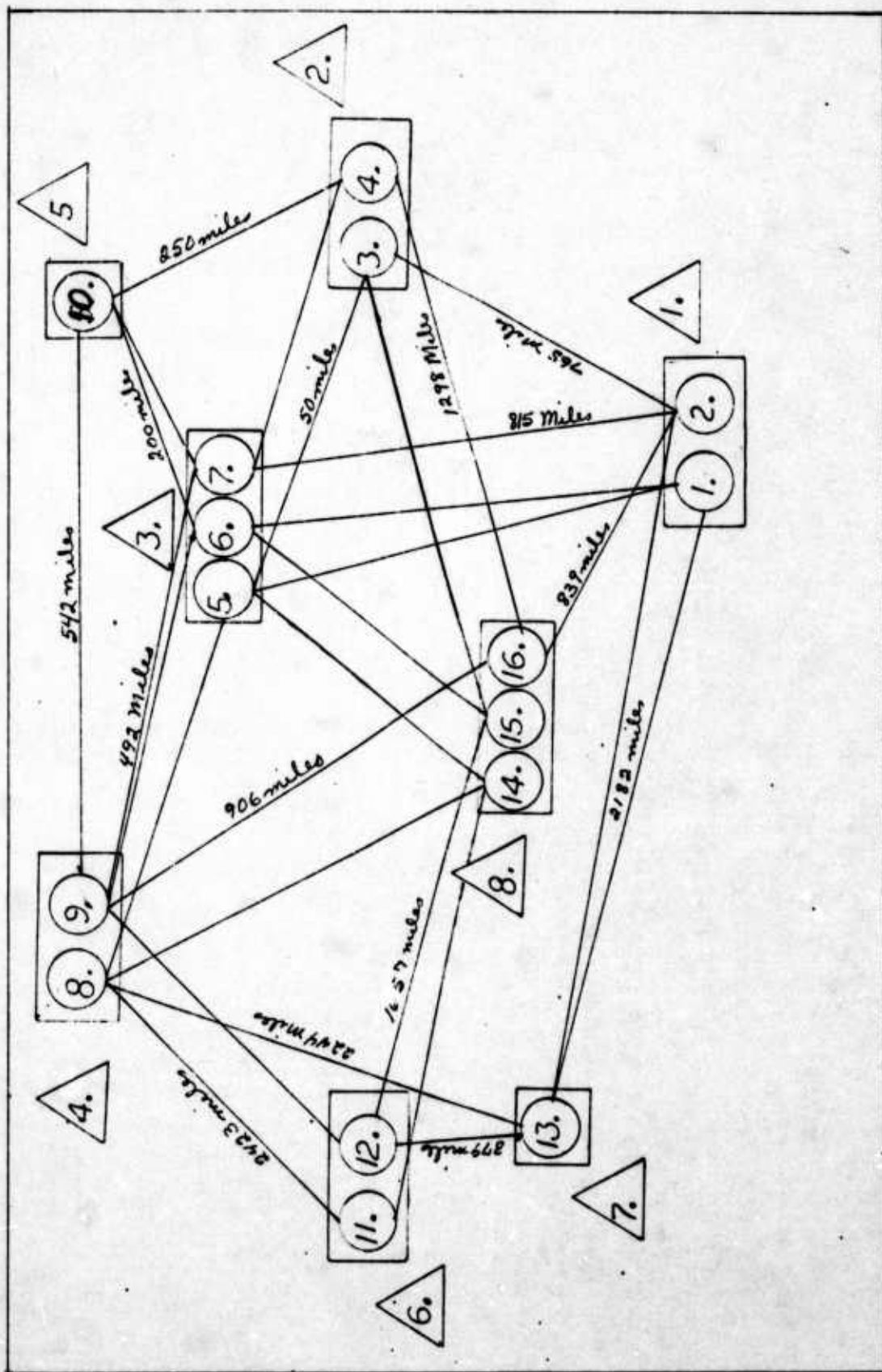
Figure A-4. Transmission Line Connectivity

one for each possible line (entries not used may be left blank). The entries are the SCM numbers of the Switch Control Module connected by transmission lines to this Switch Control Module (as represented by the SCM number in ISCM of the type 001 record).

The final information the model designer must provide to complete configuring the network is a mileage figure for each of the line connections as presented in Table A-II, and Figure A-4. Line mileage is established in the simulation network by entries into the LINDLA fields of user input record type 001. There are five of these fields; each one corresponds positionally to an ICONSCM field. If a line connection has been established in the ICONSCM field, the corresponding mileage should be entered in the LINDLA field. Otherwise, the LINDLA field should be left blank.

Traffic Load

Once the network is configured, the traffic the network will carry must be characterized. Since host computers and terminals are connected to a Packet Switching Node at the Switch Control Module level, traffic load is developed at that level. The model designer must provide traffic load arriving from outside the network at each SCM; this traffic load will be provided with units in millions of characters per hour (Figure A-5). It should not contain any character counts for network protocal, but should only count alphabetic/

TABLE A-II

LINE MILEAGE TABLE

PSN Locations	Node	Node	SCM	SCM	Mileage
Albany-Norton	1	7	1	13	2182
Albany-Fort Dietrick	1	3	1	5	815
Albany-Fort Dietrick	1	3	1	6	815
Albany-Norton	1	7	2	13	2182
Albany-Tinker	1	8	2	16	839
Albany-Fort Dietrick	1	3	2	7	815
Albany-Andrews	1	2	2	3	765
Andrews-Tinker	2	8	3	15	1298
Andrews-Fort Dietrick	2	3	3	5	50
Andrews-Tinker	2	8	4	16	1298
Andrews-Fort Dietrick	2	3	4	7	50
Andrews-Hancock	2	5	4	10	250
Fort Dietrick-Tinker	3	14	5	14	1298
Fort Dietrick-Gentile	3	8	5	8	492
Fort Dietrick-Gentile	3	8	6	9	492
Fort Dietrick-Hancock	3	5	6	10	200
Fort Dietrick-Tinker	3	8	6	15	1298
Fort Dietrick-Gentile	3	8	7	9	492
Fort Dietrick-Hancock	3	5	7	10	200
Gentile-McClellan	4	6	8	11	2423
Gentile-Norton	4	7	8	13	2244
Gentile-Tinker	4	8	8	14	906
Gentile-NcClellan	4	6	9	12	2423
Gentile-Tinker	4	8	9	16	906
Gentile-Hancock	4	5	9	10	542
McClellan-Tinker	6	8	11	14	1657
McClellan-Tinker	6	8	12	15	1657
McClellan-Norton	6	7	12	13	379
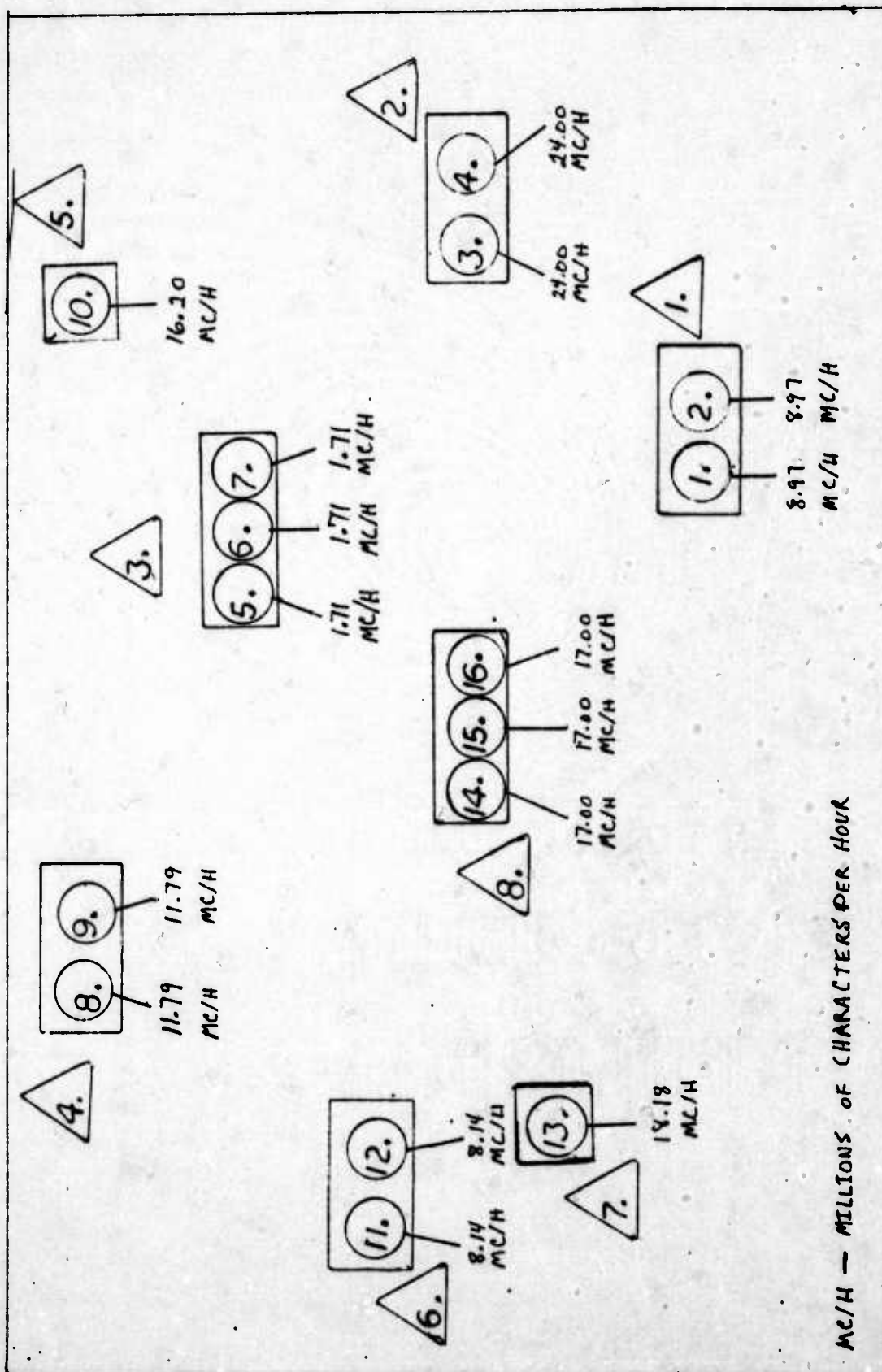
Figure A-5 Input Traffic Flow

MC/H — MILLIONS OF CHARACTERS PER HOUR

numeric data from outside the network. Programming within
the model converts the millions of characters per hour to
an arrival rate for packets in milliseconds, but to accom-
plish this the model designer must also provide the percent-
age of all packets which are short packets (75 characters
or 600 bits). This percentage is entered in the user input
record type 001 in the field labeled SHRTPKP. The remaining
packets will be long packets (588 characters or 4704 bits
long). Short packets, in general, are produced by terminals;
long packets by host computers.

The model designer may want to gather statistics on a
segment (or even two portions) of traffic load. Therefore
two fields are provided in the input user type 001 record for
traffic load. One is labeled GNMCHRS. If only one total
count is provided for traffic load it should be entered in
this field. The other field is labeled SPMCHRS. When both
fields have counts (in millions of characters per hour) entered
into them a percentage of the packets generated, corresponding
to each field's percentage of the total traffic, is uniquely
identified as from that source and statistics may be accu-
mulated concerning both or either segment of traffic load.
However, only long packets are identified as originating
from SPMCHRS.

Packets carry a precedence (or priority) level. There
are four levels, Categories I through IV. Since precedence
determines processing priority, the model designer must de-

termine what percentage of AUTODIN II packets will be assigned each precedence level. Table A-III and Table A-IV detail the decisions made concerning source traffic load for the example network.

Another aspect of traffic load which must be provided is a means of determining the destination of each packet. The model designer must provide two percentage distributions to accomplish this purpose. Each percentage distribution is entered at the Switch Control Module level. All traffic leaving the SCM must be directed to one of eight Packet Switching Nodes. The first percentage distribution determines the percentage of the packets originating at the SCM which are directed to each of the Packet Switching Nodes. These percentages are entered in the input record type 002 in the fields labeled NODTRAP, NODTRP2,···, NODTRP8. These percentages must add to 100%. Table A-V details the decisions made for the example network.

The second percentage distribution determines the percentage of packets from other Packet Switching Nodes arriving at this Packet Switching Node which have this SCM as their destination. Figure A-6 illustrates how these percentages are related and Table A-VI records the percentages for the example network. These percentages are entered in user input record type 003 in the fields labeled SCMTRAP, SCMTRP2,···, SCMTRP8.

TABLE A-III

SHORT PACKET % TABLE

SCM Number	GNMCHRS Millions of Characters/Hour	SPMCHRS	Short Packet percentage
1	8.97	0	.38
2	8.97	0	.38
3	24.00	0	.47
4	24.00	0	.47
5	1.71	0	.25
6	1.71	0	.25
7	1.71	0	.25
8	11.79	0	.49
9	11.79	0	.49
10	16.20	0	.30
11	8.14	0	.47
12	8.14	0	.47
13	18.18	0	.24
14	17.00	0	.27
15	17.00	0	.27
16	17.00	0	.27

TABLE A-IV

PRECEDENCE % TABLE

SCM Number	Precedence CATI	Precedence CATII	Precedence CATIII	Precedence CATIV
1	.01	.99	.00	.00
2	.01	.99	.00	.00
3	.01	.99	.00	.00
4	.01	.99	.00	.00
5	.01	.99	.00	.00
6	.01	.99	.00	.00
7	.01	.99	.00	.00
8	.01	.99	.00	.00
9	.01	.99	.00	.00
10	.01	.99	.00	.00
11	.01	.99	.00	.00
12	.01	.99	.00	.00
13	.01	.99	.00	.00
14	.01	.99	.00	.00
15	.01	.99	.00	.00
16	.01	.99	.00	.00

TABLE A-V

SCM to PSN PERCENTAGES

Nodes	1	2	3	4	5	6	7	8
SCMs								
1	.14	.22	.02	.07	.06	.04	.09	.36
2	.14	.22	.02	.07	.06	.04	.09	.36
3	.12	.43	.04	.07	.12	.06	.06	.10
4	.12	.43	.04	.07	.12	.06	.06	.10
5	.05	.43	.01	.08	.06	.14	.01	.22
6	.05	.43	.01	.08	.06	.14	.01	.22
7	.05	.43	.01	.08	.06	.14	.01	.22
8	.09	.18	.02	.30	.06	.12	.07	.16
9	.09	.18	.02	.30	.06	.12	.07	.16
10	.06	.38	.03	.07	.18	.06	.06	.16
11	.06	.14	.04	.06	.05	.33	.09	.23
12	.06	.14	.04	.06	.05	.33	.09	.23
13	.15	.25	.01	.07	.11	.16	.12	.13
14	.14	.13	.02	.14	.08	.14	.07	.28
15	.14	.13	.02	.14	.08	.14	.07	.28
16	.14	.13	.02	.14	.08	.14	.07	.28
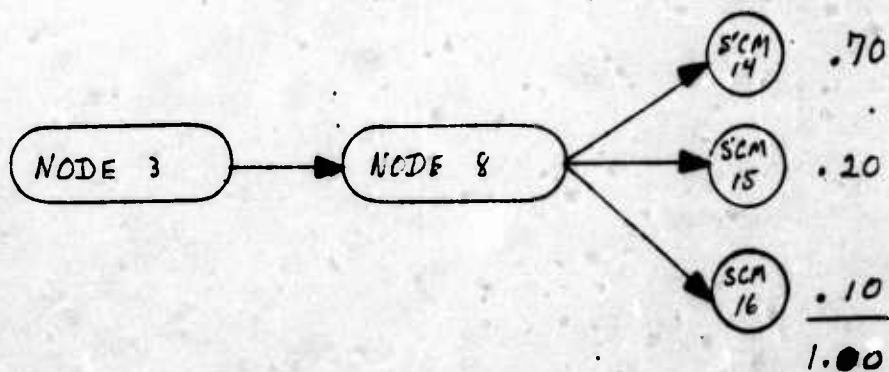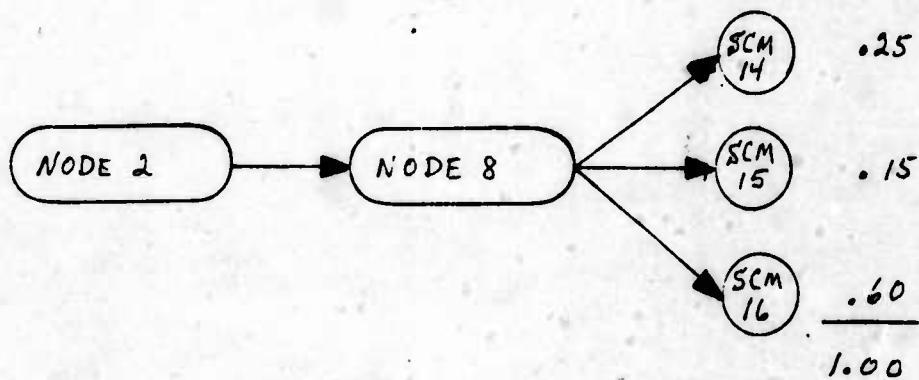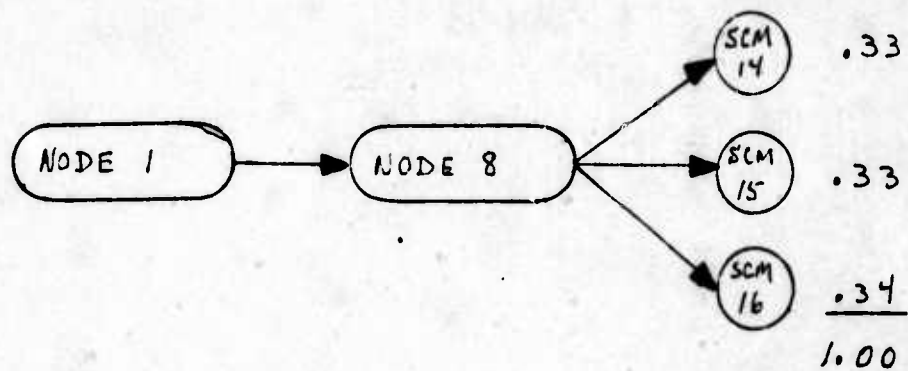
Figure A-6 Percentage Distribution for Destination SCM's

TABLE A-VI

PSN to SCM PERCENTAGES

Nodes	1	2	3	4	5	6	7	8
SCMs								
1	.50	.50	.50	.50	.50	.50	.50	.50
2	.50	.50	.50	.50	.50	.50	.50	.50
3	.50	.50	.50	.50	.50	.50	.50	.50
4	.50	.50	.50	.50	.50	.50	.50	.50
5	.33	.33	.33	.33	.33	.33	.33	.33
6	.33	.33	.33	.33	.33	.33	.33	.33
7	.34	.34	.34	.34	.34	.34	.34	.34
8	.50	.50	.50	.50	.50	.50	.50	.50
9	.50	.50	.50	.50	.50	.50	.50	.50
10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
11	.50	.50	.50	.50	.50	.50	.50	.50
12	.50	.50	.50	.50	.50	.50	.50	.50
13	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
14	.33	.33	.33	.33	.33	.33	.33	.33
15	.33	.33	.33	.33	.33	.33	.33	.33
16	.34	.34	.34	.34	.34	.34	.34	.34

Traffic Control

The remaining information the model designed must supply consists of queue levels which cause changes in the way the routing algorithm routes packets. There are up to six queues in each simulation Switch Control Module. There is a queue for incoming traffic and five (or less) queues for outgoing traffic, one for each transmission line. A saturation level is provided for each SCM in a Packet Switching Node. If the combined input queues exceed the combined saturation levels for a Packet Switching Node, the node is considered saturated and the routing algorithm will weight that as a factor in routing traffic through that node. The saturation level is entered in the user input record type 004 in the field labeled SATLEVL.

A congestion level is provided for each transmission line leaving an SCM. If the queue for that line exceeds its congestion level, that line is considered congested and the routing algorithm will weight that as a factor in routing packets over that transmission line. The congestion levels are entered in the user input record type 004 in the fields labeled CNGSTLV, CHGSTL2, ···, CNGSTL5. Table A-VII records the saturation and congestion levels for the example network.

Dynamic Changes

Dynamic changes can be made to the network configuration and to the traffic load. Lines can be dropped and

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TABLE A-VII

SATURATION AND CONGESTION LEVELS

SCM Number	Saturation Level	Congestion Levels					Number of Lines
		1	2	3	4	5	
1	9	7	7	7			3
2	9	7	7	7	7		4
3	9	7	7	7			3
4	9	7	7	7			3
5	6	7	7	7	7		4
6	7	7	7	7	7		4
7	7	7	7	7	7		4
8	9	7	7	7	7		4
9	9	7	7	7	7	7	5
10	7	7	7	7	7		3
11	9	7	7				2
12	9	7	7	7			3
13	7	7	7	7	7		4
14	6	7	7	7			3
15	7	7	7	7			3
16	7	7	7	7			3

brought back up. Source input can be set to a very low decimal point figure to simulate no input. The percentage of short packets (and therefore long packets) can be changed during the simulation process and so can the percentage of packets in each precedence level.

Changing a line's status is accomplished by placing either a minus one (to drop the line) or a plus one (to bring the line up) in the user input record type 900 in one (or more) of the fields labeled LNSTAT1,···, LNSTAT5, and by placing a time delay in milliseconds in the corresponding field labeled LNCHTM1,···, LNCHTM5 in the same record. This will cause the line to be dropped (or brought back up) at that time in the simulation.

The quantities and percentages supplied in GNMCHRS, SPMCHRS, SHRTPKP, and the four PRECDNC fields in the input type 001 record can be changed by entering a quantity (or percentage) in a like labeled field in the input type 910 record and by entering a time delay in milliseconds in the field labeled TIME in the same record. If any field is left blank in the 910 record, no change will take place for that particular field in the corresponding quantity or percentage. It will remain as it was entered in the type 001 record. A change in any field that effects the arrival rate of packets will cause that arrival rate to be recalculated.

As an example of the uses of the 900 and 910 records, a

node may be eliminated from the network dynamically by
taking all its lines down, and by setting its source char-
acters near to zero (if set to zero the field will act
as if it were blank and no change will occur).

The use of user input to configure, load and control
the network provides flexibility in using the model. The
data definition necessary to use this flexibility is des-
cribed in the next chapter.

CHAPTER A-2

DEFINITION OF USER INPUT

Input Data Records

The user's input data is keypunched onto six types of
80 column records or cards. The cards are numbered 001, 002,
003, 004, 900 and 910. The 001, 002, 003 and 004 cards are
required for each SCM defined in the user's network config-
uration. The 900 and 910 cards are optional cards used for
dynamic changes during a simulation run. The 001 card is used
to define the user's network configuration, traffic originating
at each SCM and percentages of each type of packets. The
002 card defines the distribution of destination nodes for
packets originating at the specified node. The 003 card defines,
for each node, the distribution of terminating packets to
their destination SCM. The 004 card defines the saturation
and congestion levels for each SCM. The 900 card allows
the user to make dynamic changes in the network configuration
during the simulation run. The 910 card allows the user
to make dynamic changes in the network traffic and types
of packets. A detailed explanation of each card type and
the required user input is provided in this chapter. For ease
of describing the input and output data, the proposed AUTODIN II

network defined in Chapter A-1 will be followed as an example through the next two chapters.

Input Record 001

Since the simulation is defined at the lowest level of packet switching, the user must define all input at that level. That level is the Switch Control Module (SCM).

The user should first define the network to be simulated as shown in Figure A-4. The PSNs are uniquely identified by integers 1 through NPSN (NPSN is less than or equal to 8), and the SCMs are uniquely identified by integers 1 through NSCM (NSCM is less than or equal to 25). Next the trunks, or lines, connected to each SCM are defined. Each SCM may be connected to a maximum of five other SCMs outside its own PSN. The SCMs within a PSN are assumed to be interconnected to each other through the Parallel Communication Link (PCL). The user is required to use the PSN and SCM integer identifier on the input cards. To define the outside SCM connected to a particular SCM, the user inputs the outside SCM integer identifier (as described in the following sections). Blank or zero implies a trunk is not connected.

Once the network configuration is defined, traffic data concerning message arrivals, packet priorities and packet destinations must be defined for each SCM. Two types of input traffic can be defined: General traffic (GNMCHRS) and Special traffic (SPMCHRS). Traffic units are in millions

of characters per hour. The sum of GNMCHRS and SPMCHRS must
be greater than zero. General traffic is defined as the nor-
mal network traffic originating at this SCM. Special traffic
is defined as an additional or unique traffic load which is
to be tracked through the network. Special traffic is bulk
traffic, ie, traffic that consists of large quantities of
data, usually from a host, and is divided into large packets
to be delivered to a destination PSN. Special traffic allows
the user to analyze the effects of special or additional dis-
crete traffic loads entering the AUTODIN II network. General
and special traffic are uniquely identified on output data
files for future user analysis.

The proportion of short and long packets in the network
is defined by the user. The user specifies the percentages
of short packets (SHRTPKT) in the network. SHRTPKT must
be less than or equal to one. Long packets are determined by
the program with the following equation:

SHRTPKT + LNGPKT = 1.0

AUTODIN II packets can be assigned one of four prior-
ities, or precedence levels, depending on the proportion
of traffic of CATI, CATII, CATIII and CATIV messages. The
user can define the percentage of each of the levels of
priority (PRECDNC) of packets as they enter the network. The
assigned priority follows the packet from source to destina-
tion PSN and is available to the user in the output data.

The user's input must meet the following requirement:

$$0 \leq \text{PRECDNCi} \leq 1.0$$

$$\sum_i \text{PRECDNCi} = 1.0$$

Propagation time is determined by the distance, in miles, between the nodes. Since each user's input record is at the SCM level, the user must provide the distance between a particular SCM and the SCMs connected to it. The propagation time over any line is computed by the program by adding the time required to enter the packet into the trunk, for a particular packet type, and the distance in miles multiplied by the average propagation time for the network, ten microseconds per mile (Ref 7;V-B-33). The time to enter a packet into the trunk is defined internally in the simulation program. The actual propagation time is computed in the simulation program by the following equations:

1. For status packets
Time = 10 milliseconds + mileage / 10 miles per microsecond.

2. For short packets
Time = 20.1 milliseconds + mileage / 10 miles per microsecond.

3. For long packets
Time = 93.4 milliseconds + mileage / 10 miles per micro-

second.

The network configuration and traffic data defined in this section may now be punched on cards as defined in Table A-VIII.

The 001 cards for the network as defined in Capt. John Whittenton's thesis (Ref 4:5) will now be developed.

The first three fields of the card are self explanatory. General traffic (GNMCHRS) for each PSN was assigned the same quantities as the Systems Control Incorporation specification (Ref. 2:80). No data was available for proportioning the PSN traffic to the SCM level. Therefore, the PSN traffic will be divided evenly between the SCMs within each PSN.

To illustrate, Albany's host and terminal send traffic is 39868 BPS. Converting bits to characters (eight bits per character), seconds to hours and dividing by the number of SCMs in the Albany PSN (2), yields 8.97 million characters per hour. The GNMCHRS for each SCM is provided in Table A-IX

Next, the percent of packets originating from each PSN, to be assigned as short packets, is computed. From the data in Table IV of Capt. Whittenton's thesis (Ref 4:83), the proportion of short packets, per PSN, is obtained by dividing the number of short packets per second by the total number of packets per second. No data was available as to the proportion each SCM, within a single PSN, should be assigned. Therefore, the SCMs were assigned the same propor-

TABLE A-VIII

CARD TYPE 001 FORMAT

FORTRAN Label	Card Columns	Contents
ISCNI	1-2	SCM Identification Number
INODE	3-4	PSN Identification Number
INRSCM	5-6	Number of SCMs in this PSN
GNMCHRS	7-16	The normal, or general, traffic rate originating at this SCM, in millions of characters per hour
SHRTPKT	17-19	the percentage of total packets, originating at this SCM, to be identified as a short packet
ICONSCM	20-21 22-23 24-25 26-27 28-29	Other SCMs connected by trunk to this SCM.
SPMCHRS	30-38	Special, or identified, traffic originating at this SCM, in millions of characters per hour
LINDLA	39-43 44-48 49-53 54-58 59-63	the number of miles between this SCM and other connected SCMs (the mileage must be in the same order as the connected SCMs in ICONSCM described above).
PRECDNC	64-66 67-69 70-72 73-75	The proportion of packets to be assigned to each precedence level (highest level to lowest level, respectively).
CRDTYPE	78-80	Type of Card (001)

tions as their respective PSN.

The SCM to SCM connections are taken directly from Figure A-4. For example, SCM 2 (of the Albany PSN) is connected to four other SCMs: SCM 13 (Norton PSN), SCM 16 (Tinker PSN), SCM 7 (Fort Dietrick PSN) and SCM 3 (Andrews PSN). The first four values of ICONSCM (Table A-IX) will contain the connected SCMs: 13,16;7 and 3. The fifth value of ICONSCM will be blank, signifying no connection.

No special traffic (SPMCHRS) is identified in the example. Therefore, SPMCHRS is zero for all SCMs. However, suppose the user desired to track and analyze a specific or added workload on the network. The user would assign the expected traffic from this workload to SPMCHRS for each SCM. The output data (see Chapter A-3) would have a unique identifier for all packets generated from this special workload. An analysis could then be performed.

The estimated mileage between connected SCMs, or between PSNs, was taken from a national mileage map. The mileage to each connected SCM was input into LINDLA in the same order as the connected SCMs (ICONSCM) were entered on card 001.

In Capt. John Whittenton's thesis, precedence levels are established at only two levels, CATI as high priority and CATII,CATIII and CATIV as low (or none) priority. CATI makes up 1% of the total packets and CATII, CATIII and CATIV make up 99% of the total packets. Therefore, the first precedence level (in the 001 card) is .01, implying 1% of the

TABLE A-IX

EXAMPLE NETWORK STATISTICS

SCM	GNMCHRS	SHRTPKT	ICONSCM	PRCDNCi
1	8.97	.38	3,5,6	.01,.99,0,0
2	8.97	.38	13,16,7,3	.01,.99,0,0
3	24.00	.47	2,15,5	.01,.99,0,0
4	24.00	.47	16,7,10	.01,.99,0,0
5	1.71	.25	3.1.14.8	.01,.99,0,0
6	1.71	.25	9,10,1,15	.01,.99,0,0
7	1.71	.25	9,10,4,2	.01,.99,0,0
8	11.79	.49	11,13,14,5	.01,.99,0,0
9	11.79	.49	6,7,10,12,16	.01,.99,0,0
10	16.20	.30	4,6,7,9	.01,.99,0,0
11	8.14	.47	8,14	.01,.99,0,0
12	8.14	.47	9,13,15	.01,.99,0,0
13	18.18	.24	1,2,8,12	.01,.99,0,0
14	17.00	.27	5,8,11	.01,.99,0,0
15	17.00	.27	3.6.12	.01,.99,0,0
16	17.00	.27	2,4,9	.01,.99,0,0

packets will be priority one; the second precedence level is .99, implying 99% of the packets will be priority two; and the third and fourth levels of priority are zero, implying no packets are assigned priorities three and four.

The 001 cards for the example described above are listed in Table A-X.

Input Record 002

The 002 card allows the user to describe a destination distribution for packets originating at each of the SCMs. The 003 card, as described in the next section, allows the user to describe local SCM delivery distribution for packets originating at each of the PSNs.

To develop the data for the 002 card, the user must know what percentages of traffic, originating at each SCM, is to be delivered to each of the PSNs in the network, (including the originating PSN itself). NODTRPi is defined as the proportion of packets destined for the ith node, as shown in Figure A-7.

SCM
Input
Data
Packets
Packet
Distribution

NODTRP1
NODTRP2
.
.
.
NODTRPn
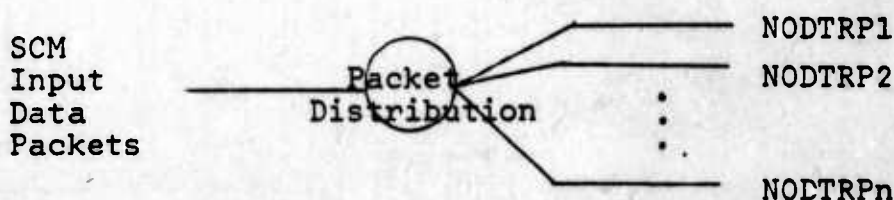
Distribution of Input Packets

Figure A-7

TABLE A-X

EXAMPLE 001 CARDS

1	1 2	8.97.3813 5 6	2182.	645.	645.	0.	0..01.99	001
2	1 2	8.97.381316 7 3	2182.	839.	839.	600.	0..01.99	001
3	2 2	22.35.47 215 5	600.1298.	839.	600.	0.	0..01.99	001
4	2 2	22.35.4716 710	1298.	50.	196.	0.	0..01.99	001
5	3 3	1.58.25 3 114 8	50.	645.1298.	392.	0.	0..01.99	001
6	3 3	1.58.25 910 115	392.	250.	645.1298.	392.	0..01.99	001
7	3 3	1.58.25 910 4 2	392.	250.	50.	645.	0..01.99	001
8	4 2	10.98.4911314 5	2423.2244.	906.	392.	0.	0..01.99	001
9	4 2	10.98.491216 6 710	2423.	906.	392.	392.	542..01.99	001
10	5 1	15.09.30 9 6 7 4	542.	250.	250.	196.	0..01.99	001
11	6 2	7.58.47 814	2423.1657.	0.	0.	0.	0..01.99	001
12	6 2	7.58.47 91513	2423.1657.	379.	0.	0.	0..01.99	001
13	7 1	16.93.24 1 2 812	2182.2182.2244.	379.	0.	0.	0..01.99	001
14	8 3	15.84.2711 8 5	1657.	906.1298.	0.	0.	0..01.99	001
15	8 3	15.84.2712 6 3	1657.1298.1298.	0.	0.	0.	0..01.99	001
16	8 3	15.84.27 9 4 2	906.1298.	839.	0.	0.	0..01.99	001

A-36

NODTRPi has the following restrictions:

$$0 \leq NODTRPi \leq 1.0$$

$$\sum_i NODTRPi = 1.0$$

The 002 card allows the user to define a wide range of traffic distribution. The data describing the distribution must be punched in the format described in Table A-XI

The 002 cards for the network described in Capt. Whittenton's thesis (Ref 4:88), will now be described. Since the example network was not developed to the SCM level, the distribution of packets to destination node will be assumed the same for all SCMs within the same PSN.

The expected exchange of packets between nodes is given in Ref 17:V-B-131. from which the distribution of data packets for each SCM was assigned and punched on the 002 cards. The 002 cards for each SCM are listed in Table A-XII.

Input Record 003

The 003 card allows the user to describe the local delivery of packets by the SCMs. When packets reach their destination PSN, the determination must be made of which SCM can deliver the packets to the host or terminal. The distribution, defined on the 003 cards, is used by the simulation program to determine the percent of packets to be delivered by each SCM within each node. In addition, the user determines the proportion of packets each SCM can de-

TABLE A-XI

CARD TYPE 002 FORMAT

FORTRAN Label	CARD Columns	Contents
ISCM	1-2	SCM identification number
INODE	3-4	PSN identification number
NODTRP1	44-48	Proportion of traffic originating at this SCM, destined for PSN 1 through 8.
NODTRP2	49-53	
NODTRP3	54-58	
NODTRP4	59-63	
NODTRP5	64-66	
NODTRP6	67-69	
NODTRP7	70-72	
NODTRP8	73-75	
CRDTYPE	78-80	Type of card (002)

TABLE A-XII

EXAMPLE 002 CARDS

1	1	.14	.22	.02	.07.06.04.09.36	002
2	1	.14	.22	.02	.07.06.04.09.36	002
3	2	.12	.43	.04	.07.12.06.06.10	002
4	2	.12	.43	.04	.07.12.06.06.10	002
5	3 3	.05	.43	.01	.08.06.14.01.22	002
6	3 3	.05	.43	.01	.08.06.14.01.22	002
7	3 3	.05	.43	.01	.08.06.14.01.22	002
8	4	.09	.18	.02	.30.06.12.07.16	002
9	4	.09	.18	.02	.30.06.12.07.16	002
10	5	.06	.38	.03	.07.18.06.06.16	002
11	6	.06	.14	.04	.06.05.33.10.22	002
12	6	.06	.14	.04	.06.05.33.10.22	002
13	7	.15	.25	.01	.07.11.16.12.13	002
14	8	.14	.13	.02	.14.08.14.07.28	002
15	8	.14	.13	.02	.14.08.14.07.28	002
16	8	.14	.13	.02	.14.08.14.07.28	002

liver based on each packet's source PSN. That is, the user
may specify that a particular SCM in a node is to deliver
more packets than another SCM in the same node, and also
specify a particular SCM to deliver a larger proportion of
traffic from one node than from another node.

Let SCMTRP(i,j) be the proportion of traffic from node
(i) to SCM (j). Figure A-8 describes the user input required
for SCM (j).
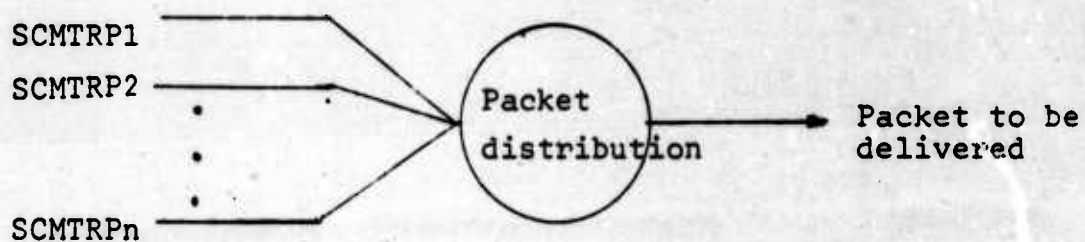
Distribution of Packets at a node to
be delivered by a particular SCM

Figure A-8

The user input must meet the following conditions for
j:

$$0 \leq SCMTRP(i,j) \leq 1.0$$

$$\sum_i SCMTRP(i,j) = 1.0$$

A-40

The format of the 003 card is described in Table A-XIII.

Again, returning to the network being developed from Capt. Whittenton's thesis, no delivery data is known below the PSN level. Actually, the delivery data will not be known until the AUTODIN II users (and their hosts and terminals and expected traffic loads) are defined. For this example, assume each SCM within the same node delivers data packets in the same proportions. For example, if a node contains two SCMs, each SCM will deliver 50% of the traffic destined for that node. The appropriate 003 cards are shown in Table A-XIV.

Input Record 004

The 004 card allows the user to define the saturation and congestion levels for each SCM. The AUTODIN II routing algorithm uses these levels to determine if packets should be routed through or around a particular node. The PSN saturation level is a level which is compared to PSN input queue backup. When input queue backup exceeds this level, all PSN transmission links are flagged as saturated. The PSN queue backup is found by summing all its SCM input queues. The PSN saturation level is computed by summing all its SCM saturation levels. If a PSN saturation level is exceeded, all nodes are notified by network generated status packets. Packets, not destined for a saturated node, are routed around the node, i.e., another path is determined.

The link congestion level is a level which is compared to

TABLE A-XIII

CARD TYPE 003 FORMAT

FORTRAN Label	Card Columns	Contents
ISCM	1-2	SCM identification number
INODE	3-4	PSN identification number
SCMTRP1	44-48	Proportion of traffic from PSN1
SCMTRP2	49-53	to be locally delivered by
SCMTRP3	54-58	this particular SCM.
SCMTRP4	59-63	
SCMTRP5	64-66	
SCMTRP6	67-69	
SCMTRP7	70-72	
SCMTRP8	73-75	
CRDTYPE	78-80	Type of card (003)

TABLE A-XIV

EXAMPLE 003 CARDS

1	1	.50	.50	.50	.50	.50	.50	003
1	2	.50	.50	.50	.50	.50	.50	003
1	3	.50	.50	.50	.50	.50	.50	003
2	4	.50	.50	.50	.50	.50	.50	003
3	5	.33	.33	.33	.33	.33	.33	003
3	6	.33	.33	.33	.33	.33	.33	003
3	7	.34	.34	.34	.34	.34	.34	003
4	8	.50	.50	.50	.50	.50	.50	003
4	9	.50	.50	.50	.50	.50	.50	003
5	10	1.0	1.0	1.0	1.0	1.0	1.0	003
6	11	.50	.50	.50	.50	.50	.50	003
6	12	.50	.50	.50	.50	.50	.50	003
7	13	1.0	1.0	1.0	1.0	1.0	1.0	003
8	14	.33	.33	.33	.33	.33	.33	003
8	15	.33	.33	.33	.33	.33	.33	003
8	16	.34	.34	.34	.34	.34	.34	003

the link queue backup. When the link queue backup exceeds
this level the link is flagged as congested. The PSN con-
gestion level is determined from the average of the SCM
congestion levels of each trunk making up a link (a trunk is
a two way communication line, where as a link is a logical
description of all trunks connecting two links). The PSN
queue backup is found by computing the average of the output
(trunk) queues making up a particular link. If a link is
declared congested, all nodes in the network are notified
through the generation of network status packets. Packets are,
if possible, routed around the congested link or links.

The user must define the saturation level for each SCM
and the congestion level for each trunk of an SCM. There are
no limits for these values. However, saturation and congestion
levels less than or equal to zero are meaningless. Also,
saturation and congestion levels that are too high will not
allow for a dynamic routing algorithm. That is, no matter
how backed up the queues get, unless the queues exceed satura-
tion or congestion levels the routing algorithm will not
change its routing paths.

The format for the 004 card is described in Table A-XVI

The saturation and congestion levels used in Capt.
Whittenton's thesis (Ref 4:34), are shown in Table A-XV.

TABLE A-XV

SATURATION AND CONGESTION LEVELS

TABLE A-XVI

CARD TYPE 004 FORMAT

FORTRAN Label	Card Columns	Contents
ISCM	1-2	SCM identification number
INODE	3-4	PSN identification number
SATLEVEL	7-15	Saturation level for this SCM (Node saturation level is determined by summing SATLEVELs of all SCMs within the node).
CNGST1	39-43	Congestion level for the link
CNGST2	44-48	corresponding to ICONSCM on
CNGST3	49-53	the 001 card.
CNGST4	54-58	
CNGST5	59-63	
CRDTYPE	78-80	Type of card (004).

Saturation Threshold (1, 2 and 3 SCMs)   7,18,20

Congestion Threshold per trunk   7

These values were divided among the SCMs as shown in the listing of 004 cards for each SCM in Table XVII.

Input Record 900

This card allows the user to simulate a network failure. A line, link, SCM or PSN can be disconnected or connected at a predetermined time during the simulation. As with the previous cards, each card provides information for only one SCM. Also, for each disconnect or connect action a separate card is required. Therefore, two cards are required to bring down an SCM at a time T1 and bring it up again at a time T2; one specifying all lines in the SCM to be brought down at time T1, and the second specifying all lines to be brought up at time T2. To disconnect (or connect) a link may require more than one card because the lines of two or more SCMs within the same PSN may make up that link. To disconnect (or connect) a PSN all lines of all SCMs within the PSN must be disconnected (or connected).

The format of the 900 card is shown in Table A-XVIII. The lines (LNSTATi) on the 900 card reference the lines connecting ISCM to other SCMs in the same sequential order as input on the 001 card. LNSTAT may be coded as 1, -1, 0 or blank, with the following definitions:

TABLE A-XVII

EXAMPLE 004 CARDS

TABLE XVIII

CARD TYPE 900 FORMAT

FORTRAN Label	Card Columns	Contents
ISCM	1-2	SCM identification number
INODE	3-4	PSN identification number
LNSTAT1	20-21	Line Status - LNSTAT(i) must
LNSTAT2	22-23	correspond in order with ICONSCM
LNSTAT3	24-25	on the 001 card.
LNSTAT4	26-27	
LNSTAT5	28-29	
LNCHTM1	38-43	the time (in milliseconds)
LNCHTM2	44-48	into the simulation run to
LNCHTM3	49-53	change the lines status as
LNCHTM4	54-58	indicated by the LNSTAT(i)
LNCHTM5	59-63	code.
CRDTYPE	78-80	Card type (900).

1. LNSTAT = 1, implies the line is to be connected at time LNCHTM.

2. LNSTAT = -1, implies the line is to be disconnected at time LNCHTM.

3. LNSTAT = 0 or blank, implies no change in the line (LNCHTM is not edited).

LNCHTM is the time (in milliseconds) into the simulation run that LNSTAT is to occur. For LNCHTM to be meaningful, it must be greater than zero and less than the maximum simulation run time.

If the user desires to bring down the Albany (PSN 1) to Norton (PSN 7) link at time 350 milliseconds into the simulation and to bring the link back up at time 500 milliseconds into the simulation, four cards would be required to perform the following actions (reference Figure A-4).

1. Bring down line 1 of SCM 1 of PSN 1 at time 350.

2. Bring down line 1 of SCM 2 of PSN 1 at time 350.

3. Bring up line 1 of SCM 1 of PSN 1 at time 500.

4. Bring up line 1 of SCM 2 of PSN 1 at time 500.

The cards for the above actions would appear as follows:

1 1	-1	350	900
2 1	-1	350	900
1 1	1	500	900
2 1	1	500	900

An alternate method of doing the same thing would be to disconnect and connect the link at the Norton (PSN 7) end, which has only one SCM. Then the above four actions could be reduced to two actions:

1. Bring down line 1 and line 2 of SCM 13 of PSN 7 at time 350.

2. Bring up line 1 and 2 of SCM 13 of PSN 7 at time 500.

The cards for these actions would appear as follows:

13	7	-1	-1	350	350	900
13	7	1	1	500	500	900

Input Record 910

This card allows the user to make certain changes in the traffic scenario during a simulation run. For any SCM the following parameters can be redefined at any specified time:

1. General traffic (GNMCHRS).

2. Percentage of short (and long) packets (SHRTPKT).

3. Special traffic (SPMCHRS).

4. Percentage of each precedence (priority) level.

The user's input for the GNMCHRS, SHRTPKT, SPMCHRS and PRECDNC levels must satisfy the same limits imposed on the input variables of the 001 card. In addition, if GNMCHRS,

SHRTPKT or SPMCHRS are zero or blank, no change will occur; that is, these values must be greater than .0001, for a change to occur. Also, the sum of the precedence levels must equal 1.0 for a change to occur.

Allowing these values to change during a simulation run will provide the user with data to analyze the results of:

1. Spikes in traffic at one or more SCMs or PSNs,

2. Increases or decreases in regular or bulk traffic.

3. Changes in priority levels (CATI, CATII, CATIII and CATIV messages).

Once a parameter has been assigned a new value, it will remain at that value unless another card is input to change it again.

The format of the 910 card is given in Table A-XIX.

Cintinuing with the example, if the user wants to investigate the results of a 150 millisecond, 200% spike in General traffic at the Andrews node (node 1), two actions would take place (assume the spike is to begin at 200 milliseconds into the simulation and end at 350 milliseconds):

1. Double the General traffic parameter (GNMCHRS) for SCM 1 and SCM 2 of PSN 1 at time 200.

2. Reinput the original GNMCHRS for SCM 1 and SCM 2 of PSN 1 at time 350.

The cards for the above actions would appear as follows:

1 1   17.94   350   910

TABLE A-XIX

CARD TYPE 910 FORMAT

FORTRAN Label	Card Columns	Contents
ISCM	1-2	SCM identification number
INODE	3-4	PSN identification number
GNMCHRS	7-16	General traffic originating at this SCM (in millions of characters per hour).
SHRTPKT	17-19	Percentage of short packets originating at this SCM.
SPMCHRS	30-38	Special, or identified, traffic originating at this SCM (in millions of characters per hour).
TIME	39-43	The number of milliseconds into the simulation the action will take place.
PRECDNC	64-66 67-69 70-72 73-75	Four precedence (priority) levels containing the probability of traffic for each SCM.
CRDTYPE	78-80	910

2	1	17.94	350	910
1	1	8.97	500	910
2	1	8.97	500	910

This chapter has discussed how to code the input data for the simulation program. Card types 001, 002, 003 and 004 are used to define the user's network configuration and traffic. Card types 900 and 910 are used to define dynamic changes during the simulation run. Chapter A-3 describes the output files (TAPE1, TAPE2, TAPE3 and TAPE4) generated during the simulation. TAPE4 will be the file of most concern to the user for normal network analyses. Unique, or special, analyses may require changes or reformating of the output files. For this purpose, each of the output files are defined in Chapter A-3.

CHAPTER A-3

DEFINITION OF DATA OUTPUT

Introduction

The AUTODIN II network simulation output listings will
be described in this chapter by presenting an explanation
of the four disk files used in the program: TAPE1, TAPE2
TAPE3 and TAPE4. Figure A-9 provides an overview of the
complete simulation and analysis program. TAPE1 contains a
listing of all the Q-GERT output data. TAPE2 and TAPE3
are data files used in reducing and reformating the data
records from TAPE1. TAPE4 is the data file used for statis-
tical analysis of the network simulation. Unless the user
requires additional or unique analysis of a network, TAPE4
will provide sufficient data, in a usable format, for most
statistical analyses. This chapter will provide the user
with a description of the output data and sufficient infor-
mation so that the user may make changes in the data reduction
programs.

TAPE1

The TAPE1 disk file contains all output records from
the Q-GERT modeling and analysis program. It may be considered
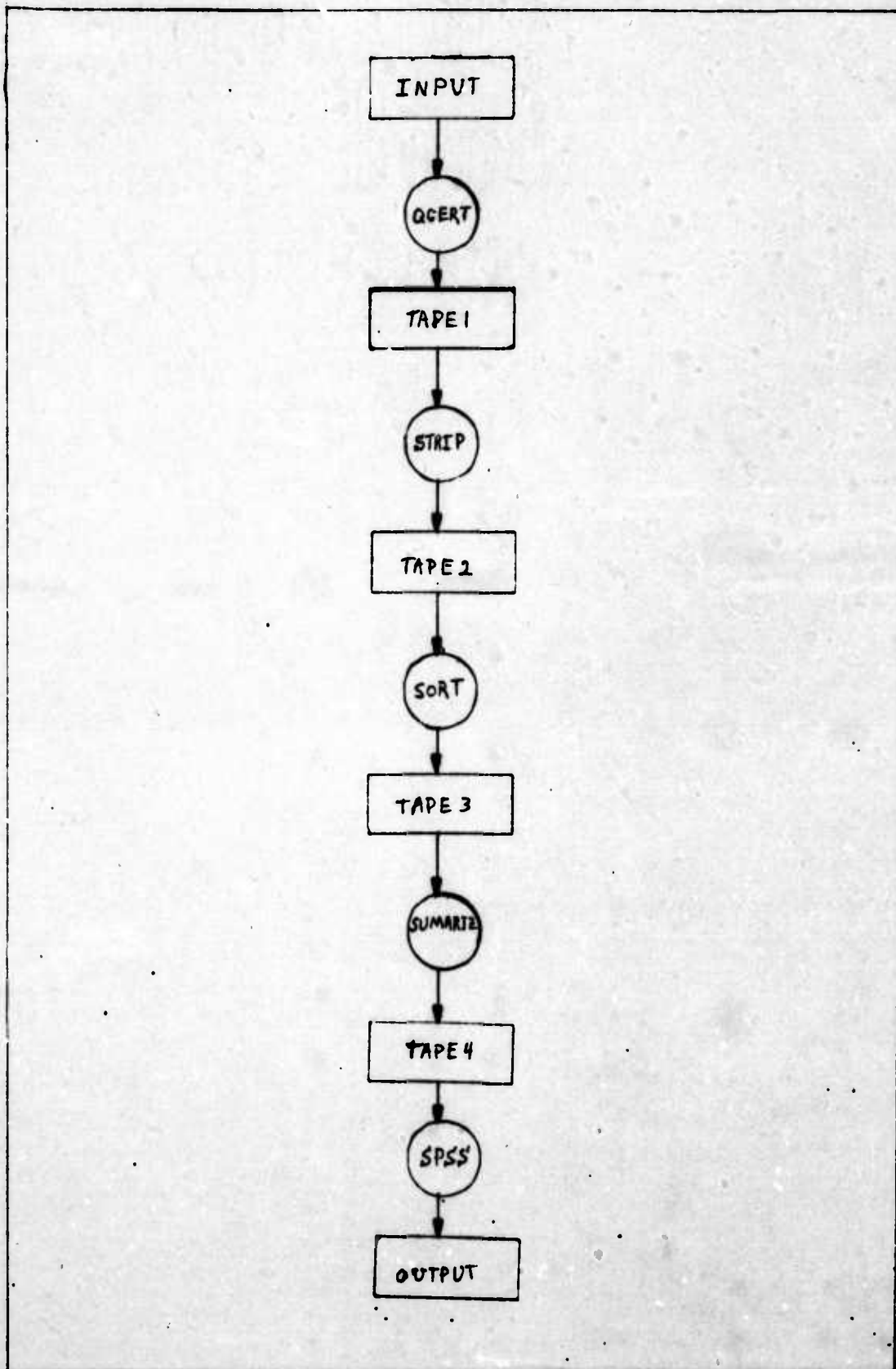
Figure A-9. Simulation Program Overview

to consist of two parts: the Q-GERT summary data and the
trace data. The summary data is provided for each simula-
tion run by the Q-GERT program. For an explanation of the
summary data, the user should study Pritsker's text (Ref
8:52). The trace data is a chronological listing of all
packet activities from the time a packet enters the network
to the time it is discarded or delivered from the network.
It is important to note the quantity of data that can be
generated in the trace data. For the example being followed
in this manual, a 45,000 millisecond simulation at 20% of
the network capacity produced over 60,000 output lines on
TAPE1 (due primarily to the trace data). However, the trace
data is very valuable in providing detailed data for the
AUTODIN II network analysis. As each packet traverses through
the simulated network, each packet's activities are recorded.
These activities include: when a packet entered the network,
when it entered and left each SCM's input queue, when it
entered and left the trunk queue, time spent on the trunk
line, and when and where the packet was discarded or de-
livered. For each activity, values for the following data
name variables are written onto TAPE1 (Ref 8 for defini-
tions).

1. Q-GERT START NODE

2. Q-GERT ENDNODE

3. ACTIVITY NUMBER

4. START TIME (milliseconds)

5.   END TIME (milliseconds)

6.   ACTIVITY NUMBER

7.   MARK TIME (milliseconds)

8.   TRANSACTION NUMBER

9.   PACKET ATTRIBUTES(10):

    1.   Packet type: status packet, short data
       packet or long data packet.

    2.   Priority level: system packet, CATI, CATII,
       CATIII or CATIV.

    3.   Source SCM

    4.   Destination SCM

    5.   Departure SCM (SCM from which the packet will
       depart this node).

    6.   Departure line (line or trunk from which the
       packet will leave the departure SCM to reach
       the next SCM).

    7.   Processing Time

    8.   SCM the packet is presently visiting.

    9.   Time, in milliseconds, for the packet to be
       loaded into the output line or transmitted
       to the destination SCM.

    10. Code to identify the packets source work-
        load: General or Specific.

The STRIP program (Appendix B) reads TAPE1 and writes the
Q-GERT summary data onto the output file for printing and
writes the selected packet activities from the Q-GERT trace
data onto TAPE2. TAPE1 is then returned.

TAPE2

    TAPE2 contains the packet activities that were initiated

at the following Q-GERT nodes:

1. Q-GERT node 8, the beginning of the processor activity.

2. Q-GERT node 10, the beginning of the activity to discard packets or to send packets to another SCM within the same PSN.

3. Q-GERT nodes 16 through 20, the beginning of the activity to transmit packets to another SCM within another PSN.

4.. Q-GERT node 21, the beginning of the activity to deliver packets to a host or terminal.

Records containing information about the AUTODIN II network configuration (input by the user on the 001 card) are also selected to provide a cross reference between PSNs and SCMs required in the SUMARIZ program (discussed later).

These selected packet activities contain the SCMs and PSNs that each packet visited in the network. They will also allow for computing the times each packet spent in the input and output queues, the time for SCM processing, whether or not a packet was placed on the PCL, and the time required for loading and transmission on the output trunks. Each packet activity record is in a reduced format as shown in Table A-XX.

TABLE A-XX

TAPE2 RECORD FORMATS

Q-GERT Name	Card Columns
STARTNODE	1-9
STARTTIME	10-18

A-58

```
ENDTIME                          19-27
MARKTIME                         28-37
TRANSACTION NO.                  38-42
ATTRIBUTE(1)                     43-50
ATTRIBUTE(2)                     51-57
ATTRIBUTE(3)                     58-64
ATTRIBUTE(4)                     65-71
ATTRIBUTE(5)                     72-78
ATTRIBUTE(6)                     79-85
ATTRIBUTE(7)                     86-92
ATTRIBUTE(8)                     93-99
ATTRIBUTE(9)                    100-106
ATTRIBUTE(10)                   107-113
```

TAPE2 is then sorted by the CDC 6600 SORTMRG program (see
Appendix B) to group the packet activities. The sorted
records are placed on the TAPE3 disk file. TAPE2 is then
returned.

TAPE3

The TAPE3 file contains the sorted TAPE2 records.
Each packet's activities are grouped together and all packet
groups are sorted by MARKTIME, that is, the time the packet
entered into the network. TAPE3 is in input file for the
SUMARIZ program. SUMARIZ reduces the packet groups into a
single record of five lines or cards, and writes the records
to TAPE4. TAPE3 is then returned.

TAPE4

TAPE4 contains the AUTODIN II network data records to
be used by the user for analysis of the AUTODIN II network.
Each record provides information about a single packet's flow

through the simulated AUTODIN II network environment. Each
record takes five lines or cards and contains: general
information about the packet (when it entered the network
and the total time in the network) on card 1; and, detailed
information about the packet (when it entered the network
and the event activities in each PSN it visited) on cards
2 through 5. Fields for all eight PSNs were included in
each record (even though a packet did not visit all eight
PSNs), to allow data processing by SPSS (to be discussed
in the next section). The data on TAPE4 can easily be
punched on cards, written to magnetic tape, or placed on
permanent file. Also, if the user does not require the
detailed information on cards 2 through 5, those cards can
be stripped off by the SPSS (or other analysis) program
or not written on TAPE4 by a minor change in the SUMARIZ
program. TAPE4 record formats are defined in Table A-XXI.

TABLE A-XXI

TAPE4 RECORD FORMATS

CARD 1

SPSS Label	Card Columns	Contents
TIME	1-10	The time (milliseconds) into the simulation run a packet entered its source PSN. This time is the same as MARKTIME in the Q-GERT text.
ATT1	11-14	The type of packet: 1= status

		packet, 2= short packet and 3= long packet.
ATT2	15-18	Packet priority: 5= system priority (for status packets), 10= priority 1 (CATI), 20= priority 2 (CATII), 30= priority 3 (CATIII) and 40= priority 4 (CATIV).
ATT3	19-22	The source SCM, that is, the SCM a packet first entered, and at which time MARKTIME was initiated.
ATT4	23-26	The destination SCM, that is, the SCM a packet last visited before being routed to its destination host or terminal.
SYS	27-30	The type of workload traffic this packet was generated from: 1.0= general traffic and 2.0= special traffic.
HOP	31-34	The number of "hops" a packet takes between its source PSN and destination PSN (hop>0).
TTIME	35-44	The total time (in milliseconds) a packet spent in the network from the time it entered its source PSN to the time it left its destination PSN.

CARD 2

SPSS Label	Card Columns	Contents
X01	1-10	Time the packet spent in the input queue of PSN1.
X02	11-20	Time the packet spent in the output queue of PSN 1.
X03	21-30	Transmission time required for a packet to be placed on the trunk at PSN 1, and transmitted to the input queue of the next PSN.

X04	31-34	The sequential order a packet visited PSN1. For example, if the packet's source PSN was PSN1, the sequence is 1.0; or, if PSN 1 was the second PSN visited, the sequence is 2.0. If the PSN was not visited, the sequence is 0.0.
X05	35-44	Time the packet spent in the input queue of PSN2.
X02	11-20	Time the packet spent in the output queue of PSN2.
X07	55-64	Transmission time required for a packet to be placed on the trunk at PSN2, and transmitted to the input queue of the next PSN.
X08	65-68	The sequential order a packet visited PSN2.

CARD 3

The same as card 2, except use PSN3 and PSN4 and variables X09 through X16.

CARD 4

The same as card 2, except use PSN5 and PSN6 and variables X17 through X24.

CARD 5

The same as card 2, except use PSN7 and PSN8 and variables X25 through X32.

For an example analysis of the data on TAPE4, a listing of SPSS control cards is given in Appendix B. Users may prefer to use other statistical analysis packages or to develop their own analysis program. For an explanation of the SPSS cards, the user should study Ref 9 and 10.

The following section describes a portion of the analysis performed by the SPSS program in this thesis.

SPSS Analysis

This section explains the SPSS program (see Appendix B) used in the example simulation followed in this manual. It is not the intent to redefine the SPSS input and control cards, except as they relate to the analysis methodology. The user should reference the SPSS texts for an explanation of SPSS input cards.

The SPSS VAR LABELS and VALUE LABELS cards, shown in the SPSS listing in Appendix B, redefine the input variables for clarity in the SPSS output products.

The SPSS cards in the program listing (Appendix B) is only one example of the various SPSS analyses available. The simulation was run for 10,500 milliseconds with a dynamic change in network traffic. The SPSS cards for that simulation will be described. The user should realize that these SPSS cards may not be appropriate for other simulations. The time and type of dynamic network configuration and traffic changes will be of primary concern in developing the SPSS

analysis.

To allow the simulation to stabilize, no data was
selected from TAPE4 for the first 1000 milliseconds of the
simulation. Also, since the simulation time was 10,500
milliseconds, no data was selected after 10,000 milliseconds.
This eliminated incomplete data records due to packets not
yet reaching their destination node. The following card
provided this capability:

SELECT IF (TIME GE 1000 AND TIME LE 10000)

An overall analysis was desired for two variables: the
number of hops required for a packet to reach its destination
node (HOP), and the packet delay time (TTIME). The following
SPSS card provided the mean, variance, minimum and maximum
values, number of cases and other statistical values for the
variables:

CONDESCRIPTIVE HOP,TTIME

The simulation run was set up to dynamically increase
general traffic at two levels in the following time intervals:

1. Normal traffic between 1000 and 3000 milliseconds.
2. 130% traffic increase between 3000 and 7000 milli-
    seconds.
3. 150% traffic increase between 7000 and 10,000
    milliseconds.

Therefore, the effects of each of these changes were to be investigated. It was decided to develop a table at 250 millisecond intervals and investigate the packet delay times in each of these intervals. Furthermore, each interval was to be divided into partitions for priority levels and types of packets (status, short and long packets). This was accomplished by the following SPSS cards:

*COMPUTE TIME=250*TRUNC(TIME/250)

BREAKDOWN TABLES=TTIME BY TIME BY ATT2 BY ATT1

For each variable within each interval the following statistics were printed: sum, mean, standard deviation, variance and quantity of cases. Graphs can be developed directly from these tables to display the results.

An analysis of the input queues, output queues and transmission times for each PSN was desired. As noted in the previous section, fields are provided on each input record (TAPE4) for all eight PSNs, even though a packet visits only a few of the PSNs in the network. The PSNs that were not visited contain a zero in the hop sequence (X04 for node 1) variable. For a given PSN, if a record contains a hop sequence of zero, that record should be omitted from the statistics of that particular PSN. The following SPSS cards provide an analysis of the Albany PSN (node 1):

*SELECT IF (X04 GT 0)

A-65

CONDESCRIPTIVE X01 TO X03

The X01 to X03 variables are defined by VAR LABELS card as the input queue time, output queue time and transmission time, respectively. Similar cards would be developed for the other PSNs.

To investigate the effects of the increase in traffic on the input queues, output queues and transmission times, a combination of the cards discussed above will provide the appropriate tables. The interval size is 1000 milliseconds. The following SPSS cards are the cards used for the Albany PSN (node 1):

```
*SELECT IF (X04 GT 0)
*COMPUTE TIME=1000*(TIME/1000)
BREAKDOWN TABLES=X01 TO X03 BY TIME
```

SPSS cards for other nodes would be similar.

It was necessary to perform a statistical test on the traffic variations. Since three variations of traffic were to be tested, the Analysis of Variance (ANOVA) test was used. The design was to test the hypothesis that no difference exists between the average delay times of each of the three traffic levels, versus the null hypothesis that a difference does exist. The SPSS ANOVA test provides a complete printout of results (Ref 9). It is only necessary to define the three traffic levels for the SPSS ANOVA. This was accomplished by defining a new variable, TRAF,

such that: TRAF = 1 for the normal traffic (1000 to 3000 millisecond interval), TRAF = 2 for the 130% traffic increase (3000 to 7000 millisecond interval), and TRAF = 3 for the 150% traffic increase (7000 to 10,000 millisecond interval). The following SPSS cards provide the ANOVA of traffic levels:

```
*COMPUTE TRAF=1
*IF (TIME GE 3000) TRAF=2
*IF (TIME GE 7000) TRAF=3
ANOVA TTIME BY TRAF(1,3)/
```

ANOVA provides for multi variable tests. The user may desire to test other conditions at the same time, such as priority levels or influence of special workloads. The simulation run should be set up to vary these parameters and then they could be tested similar to the discussion just completed.

The possible variations of simulation runs and analyses are too numerous to list. Each variation depends on the objective of the analyst. It is hoped that the discussion of SPSS has provided an insight into the possible ways to analyze the user's network problems.

CHAPTER A-4

AUTODIN II

CONTROL LANGUAGE REQUIREMENTS

Introduction

Chapter A-1 of this manual described the gathering of data for the AUTODIN II model. Chapter A-2 described formatting that data for use by the model. Chapter A-3 described the format and analysis of output from the model through the use of SPSS. This is all necessary information for running the AUTODIN II model.

But not all the information needed to complete a computer run of the AUTODIN II simulation is included in the first three chapters. Another segment of information is necessary to the process. This segment includes the job control language, the necessary Q-GERT control cards, the SORTMRG control cards, and a very basic set of SPSS control cards. This information is tailored for the CDC Cyber series of computers and is presented in the next several sections.

Job Control Language

The job control language (JCL) described here assumes

that the Q-GERT simulation language package and the SPSS

package are available as linked object code rather than as

source code. The JCL follows:

```
JOB,CM233000,IO750,T750.     T790515,HENDERSON,4331
ATTACH,QGERT,XLRGQGERTSLGO,ID=T800679.
FTN,L=TEMP,SYSEDIT,B=USER.
COPYL,QGERT,USER,LGO.
LDSET,PRESET=ZERO
LGO,,TAPE1.
REWIND,LGO.
REWIND,TAPE1.
FTN.
LGO.
REWIND,TAPE2.
FILE,TAPE2,FO=SQ,BT=C,FL=150,RT=Z.
FILE,TAPE3.FO=SQ,BT=C,FL=150,RT=Z.
SORTMRG.
REWIND,TAPE3.
REWIND,LGO.
FTN.
LGO.
REWIND,TAPE4.
ATTACH,SPSS,ID=AFIT.
SPSS,D=TAPE4.
'eor'
Source code for subroutines UI, UF, US, UO
'eor'
Q-GERT control cards
User parameter cards
'eor'
Source code for STRIP
'eor'
SORTMRG control cards
'eor'
Source code for SUMARIZ
'eor'
SPSS control cards
'eof'
```

Q-GERT Control Cards

The first set of control cards which follow are for one

Switch Control Module (SCM) only. After that set, two sets

of the control cards necessary to add Switch Control Modules

to the model will be presented.

```
GEN,DIN2SIM,TRAFINC,12,7,1980,0,50,20000,10500,1,E,0,10,1,1,
                                                   ,,,,26,20*
SOU,2,0,1*  CLOCK FOR ALL SCMS
VAS,2,1,UF,0*
ACT,2,2,CO,12.5*
ACT,2,3,US,0*
SIN,3/CLOCK,1,1,D,I*
REG,25,1,1*
ACT,25,26,US,30*
SIN,26/UPDNLINE,1,1,D,I*
DEF,1*  SUBNETWORK FOR SCM #1
SOU,5,0,1,(50)10*     TAC SOURCE NODE
VAS,5,1,UF,1,(50)20*
ACT,5,5,EX,1,(50)30*
ACT,5,7,(50)40*
REG,6,1,1,(50)50*
QUE,7/INPUTBUF,(6)S/2,(50)70*  SCM INPUT QUEUE
ACT,7,8,US,1,7/PROCESSOR,(50)80*
REG,8,1,1,F,(50)90*
ACT,8,9,UF,101,(8)1,A5.LT.-.10,(50)100*
ACT,8,10,(8)2,A6.LE.0.0,(50)110*   LOCAL DELIVERY
ACT,8,11,(8)3,A6.LE.1.,(50)120*    LINE 1
ACT,8,12,(8)4,A6.LE.2.,(50)130*    LINE 2
ACT,8,13,(8)5,A6.LE.3.,(50)140*    LINE 3
ACT,8,14,(8)6,A6.LE.4.,(50)150*    LINE 4
ACT,8,15,(8)7,A6.LE.5.,(50)160*    LINE 5
REG,9,1,1,(50)170*  MAY GO TO NODE 6 OR 8 OF ANY SCM
ACT,9,21,(50)180*
SIN,21/DISCARD,1,1,D,I,(50)190*
SIN,10/LOCALDELIVERY,1,1,D,I,(50)200*
QUE,11/OUTBUFF1,(6)S/2,(50)210*  OUTPUT BUFFER FOR LINE 1
ACT,11,16,UF,102,(50)112*
REG,16,1,1,(50)130*
QUE,12/OUTBUFF2,(6)S/2,(50)240* OUTPUT BUFFER FOR LINE 2
ACT,12,17,UF,102,(50)150*
REG,17,1,1,(50)160*
QUE,13/OUTBUFF3,(6)S/2,(50)270* OUTPUT BUFFER FOR LINE 3
ACT,13,18,UF,102,(50)280*
REG,18,1,1,(50)290*
QUE,14/OUTBUFF4,(6)S/2,(50)300* OUTPUT BUFFER FOR LINE 4
ACT,14,19,UF,102,(50)310*
REG,19,1,1,(50)320*
QUE,15/OUTBUFF5,(6)S/2,(50)330* OUTPUT BUFFER FOR LINE 5
ACT,15,20,UF,102,(50)340*
REG,20,1,1,(50)350*
ESN*
```

If this were the complete set of Q-GERT control cards
a FIN* card would follow the ESN*. Control cards for two
more Switch Control Modules will be added to the set,
however.

```
DUP,2,E*  SUBNETWORK FOR SCM 2
REP,20,VAS,5,1,UF,2*
REP,30,ACT,5,5,EX,2*
REP,80,ACT,7,8,US,2,*
ESN*
DUP,3,E*  SUBNETWORK FOR SCM 3
REP,20,VAS,5,1,UF,3*
REP,30,ACT,5,5,EX,3*
REP,80,ACT,7,8,US,3*
ESN*
FIN*
```

Switch Control Module (SCM) subnetworks can be added
up to a total of 25 SCMs, with FIN* signalling the end of
the Q-GERT control cards. The number of SCM subnetworks
<u>must</u> match the number of Switch Control Modules specified
in the user parameter cards. <u>This is important.</u>

SORTMRG Control Cards

The CDC Cyber SORTMRG control cards required to sort
the output of STRIP are:

```
SORT
FILE,INPUT TAPE2(CR),OUTPUT TAPE3(CR)
FIELD,SRT3(1,5,DISPLAY),SRT2(18,9,DISPLAY),SRT1(27,16,
                                          DISPLAY)
KEY,SRT1(A,COBOL6),SRT2(A,COBOL6),SRT3(A,COBOL6)
END
```


SPSS Control Cards

The SPSS control cards can be tailored to meet the analy-

sis requirements of the user. The set presented here is

very basic and only presented as an example.

```
RUN NAME            AUTODIN II ANALYSIS
VARIABLE LIST       TIME,ATT1 TO ATT4,SYS,HOP,TTIME,
                    X01 TO X32
INPUT FORMAT        FIXED(F10.2,6F4.0,F10.2/2(3F10.2,F4.0)/
                    2(3F10.2,F4.0)/2(3F10.2,F4.0)/2(F10.2,F4.0))
INPUT MEDIAN        DISK
VAR LABELS          TIME,MARKTIME/ATT1,TYPE PF PACKET/
                    ATT2,PRIORITY/ATT3,SOURCE NODE/
                    ATT4,DESTINATION NODE/
                    TTIME,TOTAL TIME IN NETWORK/
                    X01,NODE 1 INPUT QUEUE/
                    X02,NODE 1 OUTPUT QUEUE/
                    X03,NODE 1 TRANSMISSION TIME/
                    X04,NODE 1 HOP SEQUENCE/
                    X05,NODE 2 INPUT QUEUE/
                    X06,NODE 2 OUTPUT QUEUE/
                    X07,NODE 2 TRANSMISSION TIME/
                    X08,NODE 2 HOP SEQUENCE/
                    X09,NODE 3 INPUT QUEUE/
                    X10,NODE 3 OUTPUT QUEUE/
                    X11,NODE 3 TRANSMISSION TIME/
                    X12,NODE 3 HOP SEQUENCE/
                    X13,NODE 4 INPUT QUEUE/
                    X14,NODE 4 OUTPUT QUEUE/
                    X15,NODE 4 TRANSMISSION TIME/
                    X16,NODE 4 HOP SEQUENCE/
                    X17,NODE 5 INPUT QUEUE/
                    X18,NODE 5 OUTPUT QUEUE/
                    X19,NODE 5 TRANSMISSION TIME/
                    X20,NODE 5 HOP SEQUENCE/
                    X21,NODE 6 INPUT QUEUE/
                    X22,NODE 6 OUTPUT QUEUE/
                    X23,NODE 6 TRANSMISSION TIME/
                    X24,NODE 6 HOP SEQUENCE/
                    X25,NODE 7 INPUT QUEUE/
                    X26,NODE 7 OUTPUT QUEUE/
                    X27,NODE 7 TRANSMISSION TIME/
                    X28,NODE 7 HOP SEQUENCE/
                    X29,NODE 8 INPUT QUEUE/
                    X30,NODE 8 OUTPUT QUEUE/
                    X31,NODE 8 TRANSMISSION TIME/
                    X32,NODE 8 HOP SEQUENCE/
VALUE LABELS        ATT1(1)STATUS PACKET(2)SHORT PACKET
                    (3)LONG PACKET/ATT2(5)NETWORK PRIORITY
                    (10)CAT I(20)CAT II(30)CAT III(40)CAT IV/
                    ATT3 TO ATT4(1)ALBANY(2)ANDREWS
                    (3)FT. DETRICK(4)GENTILE(5)HANCOCK
                    (6)MCCLELLAN(7)NORTON(8)TINKER
```

```
SELECT IF           (TIME GE 1000 AND TIME LT 10000)
CONDESCRIPTIVE      HOP,TTIME
*COMPUTE            TIME 250.*TRUNC(TIME/250.)
BREAKDOWN           TABLES TTIME BY TIME BY ATT2 BY ATT1/
                          TTIME BY ATT2
*SELECT IF          (X04 GT 0)
CONDESCRIPTIVE      X01 TO X03
*SELECT IF          (X08 GT 0)
CONDESCRIPTIVE      X05 TO X07
*SELECT IF          (X12 GT 0)
CONDESCRIPTIVE      X09 TO X11
*SELECT IF          (X16 GT 0)
CONDESCRIPTIVE      X13 TO X15
*SELECT IF          (X20 GT 0)
CONDESCRIPTIVE      X17 TO X19
*SELECT IF          (X24 GT 0)
CONDESCRIPTIVE      X21 TO X23
*SELECT IF          (X28 GT 0)
CONDESCRIPTIVE      X25 TO X27
*SELECT IF          (X32 GT 0)
CONDESCRIPTIVE      X29 TO X31
FINISH
```

Summary

The information supplied in this user's manual, with the noted source code and linked object code, will provide capability to run the AUTODIN II simulation model on a CDC Cyber computer with sufficient resources. Adaptation to other computers will require modification to these instructions.

APPENDIX B:

SOURCE LISTING FOR SIMULATION
ANALYSIS

```
XXX,STSA,CM23500 ,IC755,T750.  ID-NUMBER,NAME,LOCATION
MAP,PART.
LIMIT,500.
ATTACH,GGERT,XLRGGGERTSLGO,ID=T864573.
FTN,L=TEMP,SYSEDIT,B=USER.
COPYL,GGERT,USER,LGO.
LDSET,PRESET=ZERO.
LGO,,,PEI.
REWIND,LGO.
REWIND,TAPE1.
MAP,PART.
FTN,OL
,LGO.
REWIND TAPE2.
RETURN,TAPE1.
FILE,T,PE3,FO=SQ,BT=C,FL=150,RT=Z.
FILE,T,PE2,FO=SQ,BT=C,FL=150,RT=Z.
SORTMRS.
REWIND,TAPE3.
REWIND,LGO.
MAP,PART.
FTN.
,LGO.
REWIND,TAPE5.
ROUTE,TAPE5,TID=BE,ST=CSB,FID=JH1,DC=PR.
REWIND,TAPE3.
REWIND,TAPE4.
ATTACH,SPSS,ID=AFIT.
SPSS,D=TAPE4.
EXIT,S.
DMP,16,250,121.000.
7/8/9 OR "EOR
C*************************************************************
C  SUBROUTINE UI READS ALL USER INPUT DATA AND INITIALIZES THE
C  THE VARIABLE AND ARRAYS USED BY THE GGERT SIMULATION
C
```

```
C   PROGRAM. UI ALSO PERFORMS TWO OF THE BACKGROUND
C   FUNCTIONS (INITIALIZE-0 AND CONNECTIVITY) REQUIRED
C   IN MINHOP.
C*************************************************************
      SUBROUTINE UI
      COMMON/COVAR/NDE,NFTBU(500),NREL(500),NRELP(500),NREL2(500),
     1NRUN,NRUNS,NIC(500),PARAM(100,4),TBEG,TNOW
      COMMON /PARM/ ISTEM,JTRIB(6),NPRMS,IPAR(100),SCALE,IISEED(10),SSEED
     X(10)
      COMMON/UCOM2/LD(8,8),D(8,8,8),NC(8,8),LIST(5,6),HOP(8,8),
     X ROUTE(8,6),SROUTE(8,8),LINKS(5,5,25),DISTRIB(25,25)
      COMMON /UCOM1/ NSCM, NETDATA(25,15),NODESCM(5,6),VPACK,
     X DATANET(25,14),LZONE(.),NODE,KSCM,KTTICK
      COMMON /UCOM3/ TROUTE(8,8,2), ICLOCK, AIT(10),NPNODES,MXSCMND
      DIMENSION NRSCM(5),DISTANC(8,8,8),SCMEDIT(25,16)
      REAL LINKLA(5),LD(8,8),PRECONC(4),LINKDIS(8,8),MSPRHR
      INTEGER TSCM,INODE,INRSCM,ICONSCM(5),CRDTYPE
      LOGICAL BADDATA.
      EQUIVALENCE (LD(1,1),LINKDIS(1,1)),(D(1,1,1),DISTANC(1,1,1))
      DATA NRNCDES/0/,ISTICK/0/,NSCM/0/,MXSCMND/5/,CONGSTD/1.01/,CLEAP/1
     X .01/,
      DATA MSPRHR/4*3.E/,LTSPRSP/600/,ISUP0/8/,INFINIT/1000/
      DATA LINKDIS/64*1000./,NODESCM/48*1000/,HOP/54*1000/,LIST/64*1000/
      DATA NC/64*1000/,DISTANC/512*1000/,NETDATA/400*1000/,DATANET/350*1
     X 000./,LINKS/1280*0/,UPDNNOD/25/,NRSCM/16*0/
      DATA ICLOCK/0/
      BADDATA=.FALSE.
      DO 1000 I=1,8
      NODESCM(I,6)=0
      DO 1000 J=1,8
      DO 1000 K=1,20
1000  LINKS(I,J,K)=0
      DO 1010 I = 1, 25
      NETDATA(I,7) = 7
      DO 1010 J = 1, 5
```

```
1010      NET DATA(I,J+7) = 7
1020 READ (5,90) ISCM,INODE,INRSCM,GNMCHRS,SHRTPKP,(ICONSCM(I),I=1,5),
     X     SPMCHRS,(LINDLA(J),J=1,5),(PRECDNC(L),L=1,4),CRDTYPE
90   FORMAT(I2,I2,I2,F10.0,F3.0,5I2,5I2,F9.0,5=5.0,4F3.0,I5)

C
C    F (EOF(5))1280,1030
1030 WRITE (6,96) ISCM,INODE,INRSCM,GNMCHRS,SHRTPKP,(ICONSCM(I),I=1,5),
     X     SPMCHRS,(LINDLA(J),J=1,5),(PRECDNC(L),L=1,4),CRDTYPE
95   FORMAT(1H ,3I2,F16.1,F6.3,5I2,F17.9,5F8.5,4=6.3,I5)
     IF ((INCDE.LT.1).OR.(INODE.GT.25)) 1270,1040
1040 IF (CRDTYPE.EQ.0.2) 1160,1050
1050 IF (CRDTYPE.EQ.0.3) 1130,1060
1060 IF (CRDTYPE.EQ.0.4) 1200,1073
1070 IF (CRDTYPE.EQ.0.900) GO TO 1220
     IF (CRDTYPE.EQ.0.910) GO TO 1250
     IF (CRDTYPE.EQ.0.611) GO TO 1080
     WRITE (6,97)
97   FORMAT(" INVALID CARD TYPE - PRECEDING CARD.")
     BADDATA = .TRUE.
     GO TO 1020

1080 IF ((ISCM.LT.1).OR.(ISCM.GT.25)) 1250,1090
1090 IF (NRSCM(INODE,1).EQ.0.0) NRSCM(INODE,1) =INRSCM
     NRSCM(INODE,2) = NRSCM (INODE,2) + 1
     IF ((NRSCM(INODE,1).NE.INRSCM).OR.(NRSCM(INODE,2).GT.INRSCM))
     X  1460,1110
1110 NETDATA(ISCM,1) = INODE
     IF (NRNODES.LT.INODE) NRNODES = INODE
     IF (NSCM.LT.ISCM) NSCM = ISCM
     DATANET(ISCM,1) = GNMCHRS
     DO 1120 I=1,5
     NEXTSCM = ICONSCM(I)
C
C    IS - SCM CONNECTED TO ANOTHER SCM
     IF (NEXTSCM.LE.0) GO TO 1110
     ISCMQ = 15 + I
     ISCMQ = NODCV(ISCMQ,ISCM)
     NEXTSCM = NODCV(6,NEXTSCM)
     NETEU(ISCMQ) = NEXTSCM
```

```
1110      NETDATA(ISCM,I+1) = ICONSCM(I)                                   100790
1120      DATBNET(ISCM,I+1) = LINDLA(I)                                     100800
2130 DO 1130 I = 1, 4                                                       100810
          DATBNET(ISCM,I+6) = PRECDNC(I)                                    100820
          L = 1                                                             100830
1140 DO 1140  I = 1, MXSCMND                                                100840
          IF (NODESCM(INODE,I).NE.1000) L = L + 1                           100850
          NODESCM(INODE,L) = ISCM                                           100860
          NODESCM(INODE,6)=NODESCM(INODE,5)+1                               100870
          DATANET(ISCM,11) = SHRTPKP                                        100880
1150      DATANET(ISCM,12) = SPMCHRS                                        100890
          OTPKHR=((GNMCHRS+SPMCHRS)*8)/((47#8*(1.-SHRTPKP))+(8#8*SHRTPKP))  100900
          DATANET(ISCM,13)=(SPMCHRS*8)/(((1.-SHRTPKP)*TOTPKHR)*4708)        100910
          PARAM(ISCM) = 18                                                  100920
          PARAM(ISCM,2) = 6.0                                              100930
          PARAM(ISCM,3) = 16360.                                           100940
          PARAM(ISCM,1) = MSPRHR/TOTPKHR                                    100950
          GO TO 1020                                                       100960
1160      TOTALPR = 0.0                                                     100970
     DO (1170 I = 1, 4                                                      100980
          SCMEDIT(ISCM,I) = LINDLA(I+1)                                     100990
          SCMEDIT(ISCM,I+4) = PRECDNC(I)                                   101000
1170      TOTALPR = SCMEDIT(ISCM,I) + SCMEDIT(ISCM,I+4) + TOTALPR          101010
          IF (ABS(TOTALPR - 1.0).LT.0.001)  GO TO 1020                     101020
          WRITE (6,94) TOTALPR                                             101030
     94 FORMAT( 21H TOTAL DISTRIBUTION, ,F5.3,21H DOES NOT EQUAL 100%.)     101040
          ADDATA = .TRUE.                                                   101050
          GO TO 1020                                                        101060
1180 DO 1190 I =1, 4                                                        101070
          SCMEDIT(ISCM,I+8) = LINDLA(I+1)                                   101080
1190      SCMEDIT(ISCM,I+12) = PRECDNC(I)                                   101090
          GO TO 1020                                                        101100
1200 IF (GNMCHRS.NE.0) NETDATA(ISCM,7) = GNMCHRS                            101110
     DO 1210 I = 1, 5                                                       101120
          IF (LINDLA(I).NE.0) NETDATA(ISCM,I+7) = LINDLA(I)                 101130
          GO TO 1020                                                        101140
1220      NYT(3) = ISCM                                                     101150
```

```
       TT(4) = 900.
       DO 1243 J = 1, 5                                              101150
       IF (ICONSCM(I).EQ.0) 1243,1233                               101170
       ATT (1) = ICONSCM(I)                                         101190
       ATT (2) = I                                                  101200
       CALL PTIN(UPDNNOD,LINDLA(I),TNOW,ATT)                        101210
1240   CONTINUE                                                     101220
       GO TO 1020                                                   101230
1250   TT(3) = ISCM                                                 101240
       TT(4) = 910.                                                 101250
       TT(5) = GN4CHRS                                              101260
       TT(6) = SPMCHRS                                              101270
       TT(2) = SHRTPKP                                              101280
       TT(1) = 0.0                                                  101290
       TT(7) = PRECDNC(1)                                           101300
       ATT(8) = PRECDNC(2)                                          101310
       TT(9) = PRECDNC(3)                                           101320
       TT(10) = PRECDNC(4)                                          101330
       IF (LINDLA(1).GT.0.000001) CALL PTIN(UPDNNOD,LINDLA(1),TNOW,ATT)  101340
       GO TO 1020                                                   101350
1250   WRITE (5,91) ISCM                                            101360
91     FORMAT (11H BAD SCM = ,I3)                                   101370
       BADDATA = .TRUE.                                            101380
       GO TO 1020                                                   101390
1270   WRITE (6,92) INODE                                           101400
92     FORMAT (12H BAD NODE = ,I2)                                  101410
       BADDATA = .TRUE.                                            101420
       GO TO 1020                                                   101430
C      INITIALIZE A (LINK X LINE) ARRAY FOR EACH NODE.  ALSO SIGNIFY 101440
C      CONNECTIONS IN THE LINK DISTANCE TABLE BY A 1.               101450
1280   DO 1320 I = 1, NRNODES                                       101460
       DO 1320 J = 1, NRNODES                                       101470
       TOTALPR = 0                                                  101480
       DO 1290 K = 1, MXSCMND                                       101490
       IF (NODESCM(J,K).NE.INFINIT) 1290,1300                       101500
       TOTALPR = SCMEDIT(NODESCM(J,K),I+5) + TOTALPR                101510
       IF (ABS(TOTALPR-1).GT.0.001) 1310,1320                       101520
1290
1300
```

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```
1310          WRITE (6,95) I, J, (NODESCM(J,L), L=1,5)
  95  FORMAT(6H NODE ,I2,9H TO NODE ,I2,49H SCMS OUTPUT ? DO NOT EQUAL 1
     X ,5X (CARD TYPE 6.3)./10H SCMS ARE ,5I5)
              BADDATA = .TRUE.

1320  CONTINUE
      DO 9270 I=1,8
9270      WRITE(5,9200) I,I,(NODESCM(I,J),J=1,6)
9280      FORMAT(13X," NODESCM",8X,I3,40X,I2,1X,5(3X,I7),/84 X,I7)
      WRITE(5,9210)(SCMEDIT(I,J),J=1,7),I=1,7)
3210  FORMAT(" SCMEDIT ",7F5.3)
      IF(BADDATA) 1330,1340
1330  WRITE(5,9180)
9180  FORMAT(" BAD DATA IN INPUT - RUN TERMINATED")
      CALL SYSTEM(52," CHECK DATA")
      CALL DUMF(NSCM,NFSCM,0)
1340  DO 1360 I=1, NSCM
          DO 1360 J=1, NRNODES
              DO 1360 K=1, MXSCMND
              IF (NODESCM(J,K).NE.1000)  1350,1360
1350  DISTRIB(I,NODESCM(J,K)) = SCMEDIT(NODESCM(J,K), (NETDATA (I,1)+8)) +
     X
1360          CONTINUE
      WRITE (6,9600)((DISTRIB(I,J),J=1,15),I=1,16)
      WRITE (6,9610)((SCMEDIT(I,J),J=1,13),I=1,16)
      WRITE (6,9620)((PARAM(I,J),J=1,3),I=1,16)
9600  FORMAT(" DIST ",5F8.3)
9610  FORMAT(" SCMEDIT ",13F9.4)
9520  FORMAT(" PARAM ",3F9.4)
      WRITE(5,9220)((NETDATA(I,J),J=1,10),I=1,7)
9220  FORMAT(" NETDATA ",10I6)
      DO 1390 I=1, NSCM
          DO 1390 J=2, 6
C NETDATA(I,J) ARE THE SCMS FOR THIS NODE.
              L = NETDATA(I,J)
C IF NOT CONNECTED THE INPUT SCM WILL BE ZERO.
              IF (L.EQ.0) GO TO 1330
C NETDATA(L,1) IS THE DESTINATION NODE THIS NODE IS CONNECTED WITH.
```

```
C     NETDATA(I,1) IS THIS NODE.                                          101900
      LINKS(NETDATA(I,1),NETDATA(L,1),1) = -INKS(NETDATA(I,1),NETDATA     101910
     X(L,1),1) + 1                                                        101920
C     M IS THE LINK NUMBER PLUS ONE.                                      101930
      M = LINKS(NETDATA(I,1),NETDATA(L,1),1)                              101940
C     (((J-1)*10 + I) * 1000) + N * 100 + L ENCODES THE LINE NUMBER       101950
C     AND SCM FOR THIS NODE IN THE TOP THREE POSITIONS OF A FIELD AND THE 101960
C     LINK NUMBER AND SCM OF THE CONNECTED NODE IN THE BOTTOM THREE       101970
C     POSITIONS OF THE SAME FIELD.                                        101980
C                                                                         101990
      DO 1370 N = 2, 6                                                    102000
      IF (I.EQ.NETDATA(L,N)) 1380,1370                                    102010
      CONTINUE                                                            102020
1380  LINKS(NETDATA(L,1),NETDATA(L,1),M) = (((J-1)*10+I)*1000) +(         102030
     X N-1)*100+L                                                         102040
      LINKDIS(NETDATA(I,1),NETDATA(L,1)) =1.                              102050
1370  CONTINUE                                                           102060
      DO 1430 I = 1,NRNODES                                               102070
      DO 1430 J = 1,NRNODES                                               102080
      IF (LINKDIS(I,J).NE.LINKDIS(J,I)) CALL DUMP  (LD(:,1),LD(6,8),2)    102090
1430  CONTINUE                                                            102100
      WRITE(6,9300)((LINKDIS(I,J),J=1,8),I=1,8)                           102110
9300  FORMAT(" LD ",8F8.2)                                                102120
      DO 9305 J=1,8                                                       102130
9305  WRITE(6,9310)((I,(LINKS(I,J,K),K=1,12)),J=1,5)                      102140
9310  FORMAT(" NODE=",I4,"LINKS",12I8)                                    102150
      DO 1430 I = 1,NRNODES                                               102160
      L = 0                                                               102170
      DO 1420 J = 1,NRNODES                                               102180
      IF (LINKDIS(I,J).EQ.1) 1410,1420                                    102190
1410  L = L + 1                                                           102200
      NC(I,L) = J                                                         102210
1420  CONTINUE                                                            102220
1430  CONTINUE                                                            102230
      FORMAT(" NC ",8I6)                                                  102240
      WRITE(6,9320)((NC(I,J),J=1,8),I=1,5)                                102250
9320  WRITE(6,9325)((DATANET(I,J),J=1,16),I=1,16)
```

```
9325 FORMAT(" DATANET ",13F7.2,F11.7)
     WRITE (5,9326)
9326 FORMAT(" NODE    SCM  NODCV  NFTBU")
     DO 1440 J=1,6
        DO 1440 I = 5,23
           NCV = NODCV(I,J)
           NBU = NFTBU(NCV)
1440 WRITE(5,98) I,J,NCV,NBU
98   FORMAT(I5,I5,2I7)
     NODE = 1
     CALL MINHOP
     DO 1450 J = 2, NRNODES
        NODE = I
        CALL RTABLE
1450 CONTINUE
     RETURN
1450 WRITE (5,93) INRSCM, NRSCM(INODE,1), INRSCM, NRSCM(INODE,2)
93   FORMAT ( 20H INPUT NUMBER SCMS, ,I2,32H SHOULD EQUAL HELD NUMBER
    X CMS, ,I2,/,23H OR INPUT NUMBER SCMS, ,I2,35H SHOULD BE GREATER
    X THAN SCMS COUNTED, ,I2,1H.)
     BADDATA = .TRUE.
     GO TO 1020
     END
C*********************************************************************
C
C    FUNCTION UF COMPUTES THE ATTRIBUTES ASSIGNED TO EACH OF
C    THE TRANSACTION TYPES. UF ALSO CONTAINS THE ENTRY POINT
C    TO MINHOP.
C
C*********************************************************************
     FUNCTION UF(ICODE)
     COMMON/O VAR/NODE,NFTBU(500),NREL (500),NRELP(500),NRELZ(500),
    1 NRUN,NRUNS,NTC(500),PARAM(100,6),TBEG,TNOW
     COMMON /PARM/ ISTRM,JTRIB(6),NPRMS,IPIR(160),SCALE,ISEC(160),SSEED
    X (10)
```

```
      COMMON /UCOM1/ NSCM, NETDATA(25,16), NODESCM(8,6),NPACK,            1C2543
     X   DATANET(25,14),LZONE(8),NODE,KS24,KTTICK                        1C255C
      COMMON /UCOM2/LD(8,8),D(8,8),NC(5,8),LIST(5,8),HOP(8,8),           1C2650
     X   RJUTE(8,8),SROUTE(8,8),LINKS(8,9,2),DISTRIB(25,25)              1C2670
      COMMON /UCOM3/ TROUTE(8,8,2), ICLOCK, ATT(10),NRNODES,MXSCMND      1C2680
      DIMENSION DISTANC(8,3,8)                                           1C2690
      REAL LINKDIS(8,8),LD(8,8)                                          1C2700
      EQUIVALENCE (NRNODES,NNODES)                                       1C2710
      EQUIVALENCE (LD(1,1),LINKDIS(1,1)),(D(1,1,1),DISTANC(1,1,1))       1C2720
      DIMENSION CP(25),VAL(25),IQ(25),CP1(4),VAL1(4)                     1C2730
      INTEGER SCM,TESTQ,TESTSCM,OLDSCM,OLDNODE                           1C2740
      REAL LOCAL(8),BUFF(8),LINES(8)                                     1C2750
      DATA LOCAL/8*0./,BUFF/8*0./,LINES/8*0./,NLINES/0/                  1C2760
      DATA BNOM/7./,CNOM/7./,INFI/100/,TROJTE/128*0./                    1C2770
      DATA INFINIT/1000/,CLEAR/1.00/                                     1C2780
C                                                                        1C2790
C*****************************************************************       1C2800
C                                                                        1C2810
C      IF ICODE IS EQUAL TO ZERO, TRANSACTION ATTRIBUTES FOR THE         1C2820
C      FTICK OR STICK CLOCK SIGNALS ARE ASSIGNED. IF ICODE IS AN         1C2830
C      SCM IDENTIFIER, THAT IS, IF SCM EQUALS 1, 2, ...,25, TRANS-       1C2840
C      ACTION ATTRIBUTES FOR THE SIMULATED DATA PACKETS AND STATUS       1C2850
C      PACKETS ARE ASSIGNED. IF ICODE EQUAL 1) THE REQUIRED DE-          1C2860
C      LIVERY TO THE NEXT SCM OR HOST/TERMINAL IS DETERMINED. IF         1C2870
C      ICODE EQUAL 1C2 THE TRANSMISSION TIME FOR THE PACKET IS           1C2880
C      DETERMINED.                                                       1C2890
C                                                                        1C2900
C*****************************************************************       1C2910
C                                                                        1C2920
      INF=0.0                                                            1C2930
      CALL SET FT(ATT)                                                   1C2940
      IF(ICODE.LE.0)GO TO 2000                                          1C2950
      IF(ICODE.LE.25)GO TO 2020                                          1C2960
      ICODE=ICODE-100                                                    1C2970
      GO TO (2080,2110)ICODE                                             1C2980
C      COMPUTE ATTRIBUTES FOR FTICK/STICK CLOCK SIGNAL TRANSACTION       1C2990
 2020 CONTINUE                                                           1C3000
```

```
C     TT1 IS PACKET TYPE,STATUS=1                          103010
      IF=1.0                                               103020
C     TT2 IS PRIORTY,STATUS=10                             103030
      ATT(2) = 10.                                         103040
C     TT3 IS TEMPORARILY A CYCLE OF 25 TO VARY FTICK/STICK 103050
C     CLOCK SIGNALS AMONG THE SCMS.                        103060
      CLOCK=ICLOCK+1                                       103070
      IF (ICLOCK.GT.8) ICLOCK = 1                          103080
C     ATT(3)=ICLOCK                                        103090
C     THE OTHER ATT ARE NOT DEFINED YET.                   103100
C     PRINT QUANTITIES IN Q NODES FOR ICLOCK = 1           103110
      DO 2010 I=1,NSCM                                      103120
      NNOD=NODCV(7,I)                                       103130
2010  IQ(I)=XNINQ(NNOD)                                     103140
      WRITE(6,9930)TNOW,(IQ(I),I=1,NSCM)                    103150
9930  FORMAT(" ***** INPUT QUE AT ",F7.2,2315)             103160
      CALL PUTAT(ATT)                                       103170
      RETURN                                                103180
C     COMPUTE ATTRIBUTES FOR DATA PACKETS.                 103190
2020  CONTINUE                                              103200
C     INITIALIZE VARIABLES AND ARRAYS:                     103210
C     PLONG IS THE PROBABILITY OF A LONG PACKET            103220
      SCM=ICODE                                             103230
      NODE=NETDATA(SCM,1)                                   103240
      PLONG = 1.0 - DATANET(SCM,11)                         103250
      DUMY = 0.0                                            103260
      DO 2030 I=1,NSCM                                      103270
      VAL(I)=I                                              103280
      DUMY = DUMY + DISTRIB(SCM,I)                          103290
2030  CP(I) = DUMY                                          103300
      IF (ABS(DUMY-1.0).LT.0.0001) GO TO 2040              103310
      CP(NSCM) = 1.0                                        103320
      WRITE (6,9460) (CP(I),I=1,NSCM)                       103330
9460  FORMAT(" CP = ",8F8.4)                               103340
      DUMY = 0.0                                            103350
      DO 2050 I = 1, 4                                      103360
2040  VAL1(I) = (I*10)                                      103370
```

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```
          DUMY = DUMY + DATANET(SCM,I+5)
          CP1(I)=DUMY
          CONTINUE
2050   IF(ABS(DUMY-1.0).LT.0.0001) GO TO 2060
       CP1(4) = 1.0
       WRITE (6,9410) (CP1(I),I=1,4)
9410   FORMAT(" CP1 = ",4F8.4)
C      TT1 IS THE PACKET TYPE
C         SHORT DATA PACKET=2
C         LONG DATA PACKET =3
2060   IF=2.0
       ATT(10)=1.0
       N=DRAND(1)
       IF(RN.GT.PLONG) GO TO 2070
       IF = 3.0
       N = DRAND(2)
C      ATT10 IS TYPE OF PACKET WORKLOAD: 1 IS GENERAL, 2 IS SPECIAL.
       IF(RN.LE.DATANET(SCM,13)) ATT(10) = 2.0
2070   CONTINUE
C      TT2 IS PACKET PRIORTY,PRECEDENCE1 IS 10,2 IS 20, 3 IS 30, 4 IS 40
       TT(2) = DPROB(CP1,VAL1,4,2)
C      TT3 IS THE SOURCE SCM
       ATT(3)=SCM
C      TT4 IS THE DESTINATION SCM (REF. PAGE 251 OF PRITSKER)
       ATT(6)=DFROB(CP,VAL,NSCM,2)
C      OTHER ATT ARE NOT YET DEFINED
C      ALL PUT AT(ATT)
       RETURN
C      FOR PACKETS TO BE DELIVERED TO ANOTHER SCM IN THE SAME
C      NODE, COMPUTE THE SWITCHING NETWORK
2080   CONTINUE
C      COMPUTE PRESENT SCM(OLDSCM) AND NEXTSCM (THIS NODE) AND
C      CHANGE NEGATIVE ATT5 TO POSITIVE.
       OLDSC4=ATT(5)
       OLDNODE=NETDATA(OLDSCM,1)
       OLDSCM=NCOCV(9,OLDSCM)
       NEXTSCM=-ATT(5)
```

103380
103390
103400
103410
103420
103430
103440
103450
103460
103470
103480
103490
103500
103510
103520
103530
103540
103550
103560
103570
103580
103590
103600
103610
103620
103630
103640
103650
103660
103670
103680
103690
103700
103710
103720
103730
103740

```
      TT(5)=NEXTSCM                                               103749
      CALL PUT/T(ATT)                                             103750
C                                                                 103770
C LINE =-1.0, PACKETS ARE TO BE DISCARDED AT THIS SCM             103780
      IF (ATT(8).GE.-1.0) GO TO 2090                              103790
      FTRU(OLDSCM)=OLDSCM                                         103800
      RETURN                                                      103810
C                                                                 103820
C IF PACKET IS A STATUS PACKET DELIVER TO SCM INPUT               103830
C BUFFER, NODE 5                                                  103840
2090  IF((ATT(1).GE.2.0).OR.(NETDATA(ATT(4),1).NE.OLDNODE))GO TO 2100  103850
      NEXTSCM=NODCV(6,NEXTSCM)                                    103860
      FTBU(OLDSCM)=NEXTSCM                                        103870
      RETURN                                                      103880
C                                                                 103890
C IF PACKET IS A DATA PACKET, DELIVER TO SCM OUTPUT               103900
C BUFFER, NODE 8                                                  103910
2100  NEXTSCM=NODCV(8,NEXTSCM)                                    103920
      FTBU(OLDSCM)=NEXTSCM                                        103930
      RETURN                                                      103940
C                                                                 103950
C COMPUTE TIME FOR THE PACKET TO BE TRANSMITTED                   103960
C TO THE NEXT NODE.                                               103970
2110  CONTINUE                                                    103980
      WF=ATT(9)                                                   103990
      RETURN                                                      104000
      ENTRY UPDAT                                                 104010
      WRITE (5,9190)                                              104025
9190  FORMAT(" ENTERED UPDATE")                                   104030
      IF (KTTICK.EQ.1)2286,2120                                   104045
2120  CONTINUE                                                    104050
C***********************************************************      104060
C*                                                         *      104077
C* ENTRY TO MINHOP                                         *      104085
C*                                                         *      104090
C***********************************************************      104100
      ENTRY MINHOP                                                104110
      WRITE (5,9192)
9192  FORMAT(" ENTERED MINHOP")
```

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```
      DO 2130 I = 1,NRNODES
      DO 2130 J = 1,8
         HOP(I,J) = INFINIT
         LIST(I,J) = INFINIT
      DO 2130 K = 1,NRNODES
2130  DISTANC(I,J,K) = INFINIT
      DO 2150 I = 1,NRNODES
         HOP(I,I) = 0
         L = 1
      DO 2150 J = 1,NRNODES
      IF ((LINKDIS(I,J).GE.CLEAR).AND.(LINKDIS(I,J).LT.INFINIT))2147,
     X  2150
2140     HOP(I,J) = 1
         LIST(I,L) = J
         DISTANC(I,J,L) = 1
2150     DISTANC(I,I,J) = 0.0
2160  IF (LINKDIS(I,J).LT.INFINIT) L = L + 1
      DO 2270 I = 1, NRNODES
      DO 2250 K = 1, NRNODES
         IHOPCNT = 1
2170     IALL = 0
2180  DO 2240 J = 1, NRNODES
         IF (DISTANC(I,J,K).EQ.IHOPCNT)2190,2240
2190     M = 1
2200     J1 = NC(J,M)
         IF (J1.EQ.INFINIT) GO TO 2230
         IF (J1.LT.0) GO TO 2220
         IF (DISTANC(I,J1,K).GT.IHOPCNT)2210,2220
2210     DISTANC(I,J1,K) = IHOPCNT+1
         IALL = 1
2220     M = M + 1
         GO TO 2200
2230     IHOPCNT = IHOPCNT + 1
2240  CONTINUE
      IF (IALL.NE.0)  GO TO 2170
2250  DO 2270 J = 1 , NRNODES
```

```
        IHOPCNT = INFINIT
        DO 2260 K = 1, NRNODES
2260    IF (IHOPCNT.GT. DISTANC(I,J,K)) IHOPCNT = DISTANC(I,J,K)
        HOP(I,J) = IHOPCNT
        DO 2270 K = 1, NRNODES
2270    IF (DISTANC(I,J,K).GT.(IHOPCNT+1)) DISTANC(I,J,K) = INFINIT
        WRITE(6, 9330)((HOP(I,J),J=1,8),I=1,8)
9330    FORMAT(" HOP ",8F8.2)
        DO 9340 I=1,8
9340    WRITE(6,9350)(I,(DISTANC(I,J,K),K=1,8)),J=1,8)
9350    FORMAT(" ",I4," D",8F8.2)
        WRITE(6,9360)((LIST(I,J),J=1,5),I=1,5)
9360    FORMAT(" LIST ",5I7)
C*******************************************************
C
C       ENTRY TO MINHOP
C
C*******************************************************
C
C  RTABLE BUILDS TWO ROUTING TABLES, (1) SROUTE TABLE
C  IS USED IF CURRENT NODE IS THE SOURCE NODE OF THE
C  PACKET AND (2) ROUTE TABLE IS USED IF CURRENT NODE
C  IS A TANDEM NODE FOR THE PACKET. DATA FROM THE D
C  TABLE ,OUTBUFFERS AND THE HOP ARRAY ARE USED TO
C  BUILD THE TWO ROUTING TABLES. TWO WEIGHTING FACTORS
C  ARE INTRODUCED TO BIAS AGAINST CONGESTION (BWOM) AND AGAINST
C  THE USE EXTRA HOP ROUTES (CNOM).
C  INITIALIZES  NLN=NUMBER OF LINKS IN NODE
C               LINES(NLN)=NUMBER OF LINES PER LINK
C               BUFF(NLN)=NUMBER OF PACKETS IN TOTAL
C               OUTPUT LINES IN EACH LINK
C
C  SETUP LINES AND BUFF AND NLINKS FROM LINKS ARRAY
        ENTRY RTABLE
        WRITE (6,90) NODE
90      FORMAT(" ENTERED RTABLE, NODE = ",I5)
2250    NLINKS = 3
```

```
         DO 2330 I = 1,NNODES
         LINES(I) = 0.0                                               104860
         BUFF(I) = 0.0                                                104870
         LOCAL(I) = 0.0                                               104880
         NLINES=LINKS(NODE,I,1)                                       104890
         IF(NLINES.LE.0)GO TO 2300                                    104900
         NLINKS=NLINKS+1                                              104910
C     SETUP LINES(NLINKS)=NUMBER OF LINES IN NLINK                    104920
         LINES(NLINKS)=NLINES                                         104930
C     SETUP BUFF(NLINKS)=TOTAL PACKETS IN OUPUT                       104940
C     QUEUE OF EACH LINE                                              104950
         NLINES=NLINES+1                                              104960
         DO 2290 J=2,NLINES                                           104970
C     PROP SCM FROM CODE TO GET LINE NO.                              104980
         LINEQUE=LINKS(NODE,I,J)/100000                               104990
C     PROP LINE FROM CODE TO SCM                                      105000
         LINESCM=LINKS(NODE,I,J)/1000-1000*LINEQUE                    105010
C     CONVERT LINEQUE TO OGERT LINEQUE                                105020
         LINEQUE = LINEQUE + 10                                       105030
         LINEQUE=NODCV(LINEQUE,LINESCM)                               105040
         BUFF(NLINKS)=BUFF(NLINKS)+XNINQ(LINEQUE)                     105050
2290     CONTINUE                                                     105060
2300     WRITE(5,9005)NODE                                           105070
9005     FORMAT(" NODE=",I5," LINES AND BUF=")                        105080
         WRITE(5,9005)(LINES(I),I=1,8),(BUFF(I),I=1,8)                105090
9006     FORMAT(" ",8F8.1)                                           105100
C     FOLLOWING CODE IS FROM SCI DOCUMENT.                            105110
C     COMPUTE CONGESTION WEIGHT AND HOP WEIGHTS.                      105120
         W1=100.*PNOM                                                 105130
         W2=PNOM                                                      105140
C     COMPUTE WEIGHTED BUFFER LENGTHS PER LINE                        105150
         DO 2320 L=1,NLINKS                                           105160
         IF(LINES(L).GT.0.)GO TO 2310                                 105170
         LOCAL(I) = INFINIT                                           105180
         GO TO 2320                                                   105190
2310     LOCAL(L)=BUFF(L)/LINES(L)                                    105200
2320     CONTINUE                                                     105210
                                                                      105220
```

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```fortran
C     COMPUTE ROUTE AND SROUTE ARRAYS
      DO 2410 N = 1, NRNODES
      ROUTE(NODE,N)=0.
      SROUTE(NODE,N)=0.
      BEST = -INFINIT
      SBEST = INFINIT
      DO 2410 L=1,NLINKS
      ID = INT(DISTANC(NODE,N,L))
      IF((ID.LE.HOP(NODE,N).AND.(ID.LT.INFI))GO TO 2360
      IF((ID.GT.HOP(NODE,N).AND.(ID.LT.INFI))GO TO 2340
      GO TO 2410
2340  STEST = LOCAL(L) + W1 * (DISTANC(NODE,N,L)-ID) + W2
      IF(STEST.LT.SBEST)GO TO 2350
      GO TO 2410
2350  SROUTE(NODE,N)=L
      SBEST=STEST
      GO TO 2410
2360  TEST = LOCAL(L) + W1 * (DISTANC(NODE,N,L)-ID)
      STEST=TEST
      IF(STEST.LT.SBEST)GO TO 2400
      IF(TEST.LT.BEST)GO TO 2390
      GO TO 2330
2390  ROUTE(NODE,N)=L
      BEST=TEST
      GO TO 2330
2400  SROUTE(NODE,N)=L
      SBEST=STEST
      GO TO 2380
2410  CONTINUE
9000  WRITE (5,9000) NODE
9000  FORMAT(" NODE=",I5," ROUTE AND SROUTE")
3001  WRITE (5,3001) (ROUTE(NODE,I),I=1,8),(SROUTE(NODE,I),I=1,8)
3001  FORMAT(" ",8F8.1)
C     ***************************************************
C
C     ENTRY TO TROUTE
```

```
C***** ************ ***** ***** ***** ****** *****
C     SET UP TROUTE(8,8,2) ARRAY FOR ROUTING PACKETS
C     MINIMUM QUEUE LINES WHERE ELEMENTS IN THE
C     ARRAY ARE (1) THE SCM WHICH IS THE SOURCE SCM
C     FOR THE LINE (TRUNK) IN ELEMENT (2). THE LINE
C     IN ELEMENT (2) HAS MINIMUM QUEUE SIZE OF ALL
C     LINES IN A LINK FROM NODE1 TO NODE2.
C     NODE1 IS THE SOURCE OR TANDEM NODE
      NODE1=NODE
C     NSCM IS THE NUMBER OS SCMS IN NODE1
      NSCM1 = NODESCM(NODE1,6)
C     NODE2 IS THE DESTINATION NODE
      DO 2430 NODE2 = 1, NRNODES
      TROUTE(NODE1,NODE2,1)=0.0
      TROUTE(NODE1,NODE2,2) = 0.0
      IF(NODE1.EQ.NODE2)GO TO 2430
      MINQ = INFINIT
C     SCM IS THE NUMBER OF SCMS IN NODE1
      DO 2420 I = 1, NSCM1
      SCM=NODESCM(NODE1,I)
      DO 2420 LINE=1,5
C     CHECK FOR A LINE GOING TO NODE2
      TESTSCM=NETDATA(SC4,LINE+1)
      IF (TESTSCM.LT.0)  GO TO 2420
      IF(NETDATA(TESTSCM,1).NE.NODE2)GO TO 2420
C     TEST QUEUE SIZE OF TESTSCM, IF LESS THAN PREVIOUS,
C     ASSIGN TO TROUT AS OPTIONAL SC4. LINEQ IS THE
C     CURRENT NODE NUMBER FOR LINE.
      LINEQUE = LINE + 10
      TESTSCM=NODCV(LINEQUE,SCM)
      TESTQ=XNINQ(TESTSCM)
      IF(TESTQ.GE.MINQ)GO TO 2420
      TROUTE(NODE1,NODE2,1)=SC4
      TROUTE(NODE1,NODE2,2)=LINE
      MINQ=TESTQ
```

```
2020    CONTINUE
2030    CONTINUE
        WRITE(5,3002)NODE
3002    FORMAT(" NODE=",I6," TROUTE")
        WRITE(5,5003)((TROUTE(NODE,I,J),I=1,5),J=1,2)
3003    FORMAT(" ",8F6.1)
        RETURN
        END
        SUBROUTINE US(IVAL,TIME)
C  ENTRY INTO SUBROUTINE US OCCURS FOR THE PERPACKET FUNCTION OR
C  FOR THE BACKGROUND FUNCTION.  FOR THE PER PACKET FUNCTION THE
C  SCM NUMBER IS REQUIRED (SCM=1,2,...,25).  FOR THE BACKGROUND
C  FUNCTION (FTICK,STICK,TABTICK OR STATUS PACKET) SCM IS CODED ZERO.
C  THE TIME VARIABLE IS THE PROCESSOR TIME TO EXECUTE THE PER
C  PACKET OF BACKGROUND FUNCTIONS.
        COMMON/CVAR/NDE,NFTBU(500),NRFL(500),NRELP(500),NRFL2(500),
       1 NRUN,NRUNS,NTC(500),PARAM(100,4),TREG,TNOM
        COMMON /PARM/ ISTRM,JTRIB(5),NPRMS,IPAR(100),SCALE,IISE(12),SSEED
       X (15)
        COMMON /LCOM1/ NSCM, NETDATA(25,15), NODESCM(8,6),NPACK,
       Y  DATANET(25,14),LZONE(8),NODE,KS24,KTTICK
        COMMON /UCOM2/LD(8,8),D(8,8,8),NC(8,8),LIST(8,8),4OP(8,8),
       X  ROUTE(8,8),SROUTE(8,8),LINKS(8,8,20),DISTRIB(25,25)
        COMMON /LCOM3/ TROUTE(8,8,2), ICLOCK, ATT(10),NRNODES,MXSCMND
        DIMENSION DISTANC(8,8,8)
        EQUIVALENCE (LD(1,1),LINKDIS(1,1)),(D(1,1,1),DISTANC(1,1,1))
        REAL LIMKDIS(8,8),MSPRHR,LD(8,8)
        LOGICAL LOCHNGE,LINESDN
        INTEGER SCM
        EQUIVALENCE (NRNODES,NNODES)
        DATA ISTICK/0/,CONGSTD/1.61/,CLEAR/1.30/,INFINIT/1000/
        DATA MSPRHR/3.6/
        WRITE(6,9300) IVAL
9300    FORMAT(" ENTERED US, SCM = ",I2)
        CALL ET(ATT)
        SCM = IVAL
        NSCM = IVAL
```

```
      IF IVAL (KSCM) IS EQUAL TO ZERO, PERFORM MESGEN.       106340
      IF KSCM IS AN SCP IDENTIFIER, COMPUTE PROCESSOR        106350
      TIME AND ENTER THE PAKROUTE MODULE.  IF KSCM           106360
      EQUAL 20, PERFORM DYNAMIC CHANGES IN THE AUTODIN       106370
      TRAFFIC OF CONFIGURATION.                              106380
C                                                            106390
3000  IF (KSCM .LE. 0) 3100,3900                             106410
3010  IF (KSCM .LE. 25) 3010,3020                            106420
      MODE = NETDATA(SCM,1)                                  106430
C     COMPUTE PROCESSOR TIME FOR PRIORTY AND NON PRIORTY PACKETS 106440
      TIME = 5.0                                             106450
      IF(ATT(2).LT.10.1)TIME = 3.0                           106460
      CALL  PAKROUT                                          106470
      RETURN                                                 106480
3020  IF (KSCM.EQ.30) GO TO 3030                             106490
      CALL DUMFE(G8,2770038,1)                               106570
3030  CALL GETET(ATT)                                        106510
      IF (ATT(4).GT.935.) GO TO 3060                         106520
      ISUBONE = IABS(NETDATA(NETDATA(ATT(3),ATT(2)+1))       106530
      LINES=LINKS(NETDATA(ATT(3),1),NETDATA(ISUBONE,1),1) + 1 106540
      DO 3060 I = 2, NLINES                                  106550
      LNCNCT = LINKS(NETDATA(ATT(3),1),NETDATA(ISUBONE,1),I) 106560
      LINEHR = LNCNCT/100000                                 106570
      ISCMHR = (LNCNCT-(LINEHR*100000))/1000                 106580
      LINETHR = (LNCNCT-((LINEHR*100000)+(ISCMHR*1000)))/100 106590
      SCMTHR = LNCNCT-((LINEHR*100000)+(ISCMHR*1000)+(LINETHR*100)) 106570
      IF ((LINEHR.EQ.IFIX(ATT(2))).AND.(ISCMHR.EQ.IFIX(ATT(3)))) GO TO 106610
X     3051                                                   106620
3060  CONTINUE                                               106630
3051  NETDATA(ISCMHR,LINEHR+1)=ATT(1)*IABS(NETDATA(ISCMHR,LINEHR+1)) 106640
      NETDATA(ISCMTHR,LINETHR+1)=ATT(1)*IABS(NETDATA(ISCMTHR,LINETHR+1)) 106650
      RETURN                                                 106660
3050  SCM = ATT(3)                                           106670
      IF (ATT(5).GT.0.00000000021) DATANET(KSCM,1) = ATT(5)  106680
      IF (ATT(2).GT.0.0001) DATANET(KSCM,11) = ATT(2)        106690
      IF (ATT(6).GT.0.00000001) DATANET(KSCM,12) = ATT(5)    106700
```

```
      TOTPKHR= 8.*(DATANET(KSCM,12)+DATANET(KSCM,1))/((47.*6.*(1.-     106710
     X DATANET(KSCM,11))+(690.*DATANET(KSCM,11)))                      106720
      DATANET(KSCM,13)=(DATANET(KSCM,12)*5.)/((1.-DATANET(KSCM,11))    106730
     X TOTPKHR*67.4.)                                                  106740
      PARAM(KSCM,1)=MSPRHR/TOTPKHR                                     106750
      ATT(2) = 0.0                                                     106760
      DO 3070, I = 7, 15                                               106770
3070  ATT(2) = ATT(I) + ATT(2)                                        106780
      IF ((ABS(1.0-ATT(2))).GT.0.01) GO TO 3090                       106790
      DO 3090 I = 7, 15                                               106800
3090  DATANET(KSCM,I) = ATT(I)                                        106810
3031  RETURN                                                          106820
C***********************************************************           106830
C *                                                    *              106840
C *  ENTRY TO MESSAGE GENERATION (MESGEN)              *              106850
C *                                                    *              106860
C***********************************************************           106870
C***********************************************************           106880
3100  IF ((ICLOCK.EQ.1).AND.(ISTICK.EQ.40)) ISTICK = 0               106890
      IF (ICLOCK.EQ.1) ISTICK = ISTICK +1                            106900
      WRITE (5,9101) ICLOCK,ISTICK                                    106910
9101  FORMAT(" ENTERED US MESGEN, ICLOCK = ",I2,", ISTICK = ",I2)    106920
      NODE = ICLOCK                                                   106930
      NODF = ICLOCK                                                   106940
      IF (NODESCM(NODE,1).EQ.INFINIT) RETURN                         106950
      KSCM = NODESCM(NODE,1)                                          106960
      NDCHNGE = .FALSE.                                               106970
      IF (ISTICK.EQ.4) 3120,3330                                     106980
C***********************************************************           106990
C *                                                    *              107000
C *  EVERY 400 MILLISECONDS "GOOD NEWS" MUST BE CHECKED. *            107010
C *                                                    *              107020
C***********************************************************           107030
C***********************************************************           107040
C***********************************************************           107050
3120  WRITE (5,3110)                                                  107060
                                                                      107070
```

```
9110  FORMAT(" ENTERED GOODNEWS")
      DO 3270 I = 1, NRNODES
        NLINES = LINKS(INODE,I,1) + 1
        IF ((LINKDIS(INODE,I).LT.0).AND.(LINKS(INODE,I,1).NE.0)) 3130,
     X    3270
3130    DO 3220 J = 2, NLINES
          LINEHR = LINKS(INODE,I,J) / 100000
          ISCMHR = (LINKS(INODE,I,J) - (LINEHR*100000)) / 1000
          LINETHR = (LINKS(INODE,I,J)-((LINEHR*100000)+(ISCMHR*1000)))/100
          ISCMTHR = (LINKS(INODE,I,J)-((LINEHR*100000)+(ISCMHR*100)) +
     X      (LINETHR*100)))
          IF (NETDATA(ISCMHR,LINEHR+1).GT.0) 3140, 3160
3140      IF (NETDATA(ISCMTHR,LINEHR+1).GT.0) 3190, 3150
3150      NETDATA(ISCMHR,LINEHR+1) = - NETDATA(ISCMTHR,LINEHR+1)
          GO TO 3220
3160      IF (NETDATA(ISCMTHR,LINETHR+1).GT.0) 3170, 3220
3170      NETDATA(ISCMTHR,LINETHR+1) = - NETDATA(ISCMTHR,LINETHR+9)
          GO TO 3220
3180      LDCHNGE = .TRUE.
          LINKDIS(INODE,I) = CONGSTD
3220    DO 3240 K = 1, NRNODES
          IF (I.NE.IABS(NC(INODE,K))) 3190, 3210
          IF (NC(INODE,K).EQ.INFINIT) 3200, 3220
3210      CONTINUE
          NC(INODE,K) = IABS(NC(INODE,K))
3220    CONTINUE
3230    IF (LINKDIS(INODE,I).GT.1.0R1) 3240, 3270
3240    IQUEAMT = 0
        ICNTAMT = 0
        DO 3250 J = 2, NLINES
          LINEHR = LINKS(INODE,I,J) / 100000
          ISCMHR = (LINKS(INODE,I,J) - (LINEHR*100000)) / 10000
          K = NODCV(LINEHR+10,ISCMHR)
          IQUEAMT = IQUEAMT + XNINO(K)
3250      ICNGAMT = ICNGAMT + NETDATA(ISCMHR,LINEHR+7)
        IF ((IQUEAMT/(NLINES-1)).LT.(ICNGAMT/(NLINES-1))) 3260, 3270
3260    LDCHNGE = .TRUE.
```

```
327.       LINKDIS(INODE,I) = CLEAR
328D  TOUEAMT = 0
      'SATAMT = 0
      DO 3300 I = 1, MXSCMND
        IF (NODESCM(INODE,I).EQ.13.0) 3310,3290
329.      J = NODCV(7,NODESCM(INODE,I))
          IOUEAMT = IOUEAMT + XNINO(J)
3300  'SATAMT = ISATAMT + NETDATA(NODESCM(INODE,I),7)
3310  IF ((IOUEAMT.LT.ISATAMT).AND.(LZONE(INODE).EQ.1)) 3320, 3330
3320  ZONE(INODE) = 0
      DCHNGE = .TRUE.

C**************************************************************
C*
C*    VERY 10( MILLISECONDS "BAD NEWS" MUST BE CHECKED.
C*
C**************************************************************

3330  WRITE(5,9120)
9120  FORMAT(" ENTERED BADNEWS")
      DO 3500 I = 1, NPNODES
        NLINES = LINKS(INODE,I,1) + 1
        LINESDN=.TRUE.
      F ((LINKDIS(INODE,I).LT.1000).AND.(LINKDIS(INODE,I).GT.0)) 3340,
     Y  3460
3340    DO 3460 J = 2, NLINES
          LINEHR = LINKS(INODE,I,J) / 100000
          ISCMHR = (LINKS(INODE,I,J) - (LINEHR*100000)) / 1000
          LINETHR = (LINKS(INODE,I,J) -(LINEHR*100000)+(ISCMHR*1000)))/100
          SCMTHR = (LINKS(INODE,I,J) -(LINE4R*100000)+(ISCMHR*1000)+
     X   (LINETHR*100)))
          WRITE (5,9130) ISCMHR,LINE4R,ISCMTHR,LINETHR
9130  FORMAT(" ISCMHR ",I2," LINEHR ",I2," ISCMTHR ",I2," LINETHR ",I2)
          IF (NETDATA(ISCMTHR,LINEHR+1).LT.0) 3350, 3370
3350      IF (NETDATA(ISCMTHR,LINETHR+1).LT.0) 3360, 3362
3360  .ETDATA(ISCMTHR,LINETHR+1) = - NETDATA(ISCMTHR,LINETHR+1)
```

```
3370              GO TO 3470
3380       IF (NETDATA(ISCMTHR,LINET4R+1).LT.C) 3380, 3390
       NETDATA(ISCMHR,LINEHR+1) = - NETDATA(ISCMHR,LINEHR+1)
              GO TO 3400
3390          LINESDN = .FALSE.
3400          CONTINUE
3410       IF (LINESDN) 3410, 3460
       LINKDIS(INODE,I) = - LINKDIS(INODE,I)
       DO 3430 J = 1, NRNODES
3420       IF (I.NE.NC(INODE,J)) 3420, 3440
3430       IF (NC(INODE,J).NE.INFINIT) 3430, 3450
3440       CONTINUE
       NC(INODE,J) = - NC(INODE,J)
3450       LDCHNGE = .TRUE.
3460  IF ((LINKDIS(INODE,I).GT.C).AND.(LINKDIS(INODE,I).LT.-1.0E1))
     X      3470, 3550
3470       IQUEAMT = 0
       ICNGAMT = 0
       DO 3480 J = 2, NLINES
          LINEHR = LINKS(INODE,I,J) / 100000
       ISCMHR = (LINKS(INODE,I,J) - (LINEHR*100000)) / 1000
          K = NODCV(LINEHR+10,ISCMHR)
          IQUEAMT = IQUEAMT + XNINQ(K)
3480       ICNGAMT = ICNGAMT + NETDATA(ISCMHR,LINEHR+7)
3490  IF ((IQUEAMT/(NLINES-1)).GE.(ICNGAMT/(NLINES-1))) 3490, 3500
       LDCHNGE = .TRUE.
       LINKDIS(INODE,I) = CONGSTD
3500       CONTINUE
3510  IQUEAMT = 0
       ISATAMT = 0
       DO 3530 I = 1, MXSCMND
3520       IF (NODFSCM(INODE,I).EQ.1)00) 3530, 3525
          J = NODCV(7,NODESCM(INODE,I))
          IQUEAMT = IQUEAMT + XNINQ(J)
3525       ISATAMT = ISATAMT + NETDATA(NODESCM(INODE,I),7)
3530       CONTINUE
3530  IF ((IQUEAMT.GE.ISATAMT).AND.(LZONE(IVODE).EQ.0)) 3560, 3550
```

```
3549      IZONE(INODE) = 1
          LZCHNGE = .TRUE.
3550   IF (LZONE(INODE).EQ.1) 3560, 3590
3560   DO 3570 I = 1, NRNODES
3570   IF ((LINKDIS(INODE,I).GT.0).AND.(LINKDIS(INODE,I).LT.1.0D.1))
     X       LINKDIS(INODE,I) = CONGSTD
3590   IF (.NOT.LZCHNGE) 3540, 3595
3595   TTICK = 0

C**************************************************************
C
C      ENTRY TO UPDATE
C
C**************************************************************

       CALL UPDAT
       NEXTNOD = NODCV(8,KSCM)
       DO 3530 I = 1, NRNODES
       IF (I.NE.INODE) 3600, 3630
3600   CALL GETAT(ATT)
       ATT(1) = 1.
       ATT(2) = 5.
       ATT(3) = KSCM
       ATT(4) = NODESCM(I,1)
       ATT(7) = 0
       CALL PUTAT(ATT)
       CALL PAKROUT
       CALL GETAT(ATT)
C
C      ADD TIME TO PROCESSOR IF BUSY, ELSE STORE IN ATT7
       NACT=NATCV(7,KSCM)
       NNOD=NODCV(7,KSCM)
       IF(ISTUS(NNOD,NACT).GT.0)GO TO 3510
       ATT(7)=5.0
       GO TO 3620
3510   CALL XTEND(NACT,5.0)
       WRITE(6,9139)TNOW,KSCM
9139   FORMAT(" XTEND CALLED AT",F8.2,I5)
```

```
3520  CONTINUE
      CALL PTIN(NEXTNOD,I,TNOW,ATT)
3530  CONTINUE
9192  WRITE (6,9192) NEXTNOD,I,TNOW,(ATT(I),I=1,17)
      FORMAT(" IN US, PTIN ",2I4,11F6.2)
9147  WRITE (5,9147) ((LINKDIS(I,J),J=1,3),I=1,5)
      FORMAT(" LD ",8F8.2)
9150  WRITE (5,9150) ((NC(I,J),J=1,5),I=1,3)
9150  FORMAT(" NC ",6I6)
      RETURN
3540  KTTICK = 1
3550  CALL UPDAT
      RETURN
      END
C
C     SUBROUTINE UO CONTAINS THE PKROUTE MODULE
C
      SUBROUTINE UO
      COMMON/OVAR/NDE,NFTBU(500),NREL(500),NRELP(500),NREL2(500),
     1    NRIA,NFUNS,NTC(500),PARAM(100,4),TBEG,TNOW
      COMMON /EARM/ ISTFM,JTRIB,JTRIB(5),NPRMS,IPAR(100),SCALE,IISET(10),SSEED
     X    (10)
      COMMON/UCOM2/LD(8,8),DC(8,8,8),NC(5,5),IST(8,8),HJB(8,8),
     X    ROUTE(8,8),SROUTE(8,8),LINKS(3,3,20),DISTRIB(25,25)
      COMMON /UCOM1/ NSCM, NETDATA(25,15),NODESCM(5,6),NPACK,
     X    DATANET(25,14),LZONE(8),NODE,KS34,KTTICK
      COMMON /UCOM3/ TROUTE(8,8,2), ICLOCK, ATT(13),NRNODES,MXSCMND
      DIMENSION LINKDIS(8,8),DISTANC(8,8,9)
      EQUIVALENCE (LD(1,1),LINKDIS(1,1)),(D(1,1,1),DISTANC(1,1,1))
      EQUIVALENCE (NRNODES,NNODES)
      INTEGER SCM,DNODE,SNODE
      REAL LINKDIS(8,8),LD(8,8)
      REAL LOCAL(8),BUFF(8),LINES(8)
      DATA LOCAL/8*0./,BUFF/8*0./,LINES/8*0./,NLINES/8/
      DATA BNODP/7./,CNOM/7./,INFI/1000/,TROUTE/128*0./
9010  WRITE(6,9300)
9010  FORMAT(" ZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZ")
```

```
C     THE ABOVE WRITE FLAGS THE END OF THE TRACE PRINT ?????
      RETURN
C*****************************************************
C
C     ENTRY TO PAKROUTE
C
C*****************************************************
C*****************************************************
      ENTRY PAKROUT
      WRITE (6,9170) KSCM,NODE
9170  FORMAT(" ENTERED PAKROUT, KSCM = ",I5," NODE = ",I5)
      SCM=KSCM
C     PACKROUTE
C     PACKET FUNCTION
C     REFERENCE RED NO. 2, P. A-5
C     INITIALIZE
      EXTNOD = 0
      LINK2 = 0
4000  DNODE=ATT(4)
      DNODE=NETDATA(DNODE,1)
      SNODE = ATT(3)
      SNODE=NETDATA(SNODE,1)
      TT(8)=SCM
C     TEST IF THIS PACKET IS A LOCAL DELIVERY
      IF(NODE.NE.DNODE) GO TO 4030
      TT(6)=-1.0
      IF(IFIX(ATT(1)).EQ.1) 4010, 4030
4010  TTICK = 8
C     ALL UPDAT
      ATT(5)=-10.0
4030  CONTINUE
      NEXTSCM=ATT(4)
      TT(5)=NEXTSCM
C     SET ATT5 NEGATIVE IF PACKET IS TO BE DELIVERED
C     TO ANOTHER SCM (SAME NODE) OR IF A STATUS PACKET
      IF((NEXTSCM.NE.SCM).OR.(IFIX(ATT(1)).EQ.1))ATT(5)=-NEXTSCM
```

108930
108940
108950
108960
108970
108980
108990
109000
109010
109020
109030
109040
109050
109060
109070
109080
109090
109100
109110
109120
109130
109140
109150
109160
109170
109180
109190
109200
109210
109220
109230
109240
109250
109260
109270
109280
109290

```
4031    GO TO 4170
        CONTINUE
C      .IF A SOURCE NODE USE SROUTE, IF A TANDEM NODE USE
C       ROUTE - .TO DETERMINE NEXT NODE
        IF (SNODE.EQ.NODE)GO TO 4060
C       CONVERT. OUTGOING LINK TO NEXTNODE
        NLINK1 = ROUTE(NODE,DNODE)
        IF (NLINK1.LE.0) GO TO 4090
4040    DO 4040 I = 1, NRNODES
           IF (LINKS(NODE,I,1).GT.0) NLINK2 = NLINK2 + 1
           IF (NLINK2.EQ.NLINK1) GO TO 53
9175    WRITE (5,9116) NLINK1
        FORMAT(" NEXTNODE NOT FOUND FROM ROUTE ARRAY, NLINK1.",I4)
        GO TO 4090
53      NEXTNOD = I
        GO TO 4090
C       CONVERT OUTGOING LINK TO NEXTNODE
4060    LINK1 = SROUTE(NODE,DNODE)
        IF (NLINK1.LE.0) GO TO 4090
4070    DO 4070 I = 1, NNODES
           IF (LINKS(NODE,I,1).GT.0) NLINK2 = NLINK2 + 1
           IF (NLINK1.EQ.NLINK2) GO TO 4080
9110    WRITE (5,9110) NLINK1
        FORMAT(" NEXTNODE NOT FOUND FROM SROUTE ARRAY, NLINK1.",I4)
        GO TO 4090
4080    NEXTNOD = I
C      .IF UNABLE TO DELIVER PACKET (NEXTNOD=0),DISCARD PACKET
4090    IF (NEXTNOD.NE.0)GO TO 4100
        TT(5)=-SCM
        TT(5) = -16.
        GO TO 4170
C       USE TROUTE TO DETERMINE WHICH TRUNK TO USE TO
C       DELIVER PACKET
4100    EXRSCM=TROUTE(NODE,NEXTNOD,1)
        VRTIM = 93.4
        IF(ATT(1).LT.2.99) ENTRTIM = 20.1
        IF(ATT(1).LT.1.99) ENTRTIM = 15.
```

```
C     F NEXTSCM EQ C,SCM IS NOT CONNECTED - DISCARD
      F(NEXTS CM.GT.C)GO TO 4110
      TT(5)=-SCM
      TT(5) = -10.
      GO TO 4130
C     F NEXTSCM EQ THIS SCM, THEN DETERMINE DELIVERY LINES
4110  F(NEXTSCM.NE.SCM)GO TO 4120
      TT(5) = .SCM
      TT(5)=TROUTE(NODE,NEXTNOD,2)
      TT(3) = (DATANET(KSCM,TROUTE(NODE,NEXTNOD,2)+1)/235.)+ENTRTIM
      GO TO 4130
C     PACKET S TO BE SENT TO ANOTHER SCM IN THIS NODE
C     (CODE THE SCM NEGATIVE TO PASS TO QSERT NODE 9)
4120  INE=TROUTE(NODE,NEXTNOD,2)
      TT(5)=-NEXTSCM
      TT(5) = TROUTE(NODE,NEXTNOD,2)
      TT(3) = (DATANET(KSCM,TROUTE(NODE,NEXTNOD,2)+1)/185.)+ENTRTIM
4130  ALL PJTAT(ATT)
      WRITE(5,9007)NODE,SCM
9007  FORMAT(" NODE=",IE,"SCM=",I6,"ATT IN PACKROUTE")
      WRITE(5,9008)(ATT(I),I=1,6)
9008  FORMAT(" ",16F8.2)
      RETURN
      END
GEN,DTN2SIM,SPIKE,7,31,1980,0,50,2630°,2G),1,E,0,10,1,1,,,,26,20*
SOU,2, ,1"CLOCK FOR ALL SCMS
VAS,2, ,UF,0*
ACT,2, ,CO,12.5*
ACT,2, ,US,7*
SIN,3/-LOCK,1,1,D,I*
REG,2c,1,1*
ACT,25,26,US,3**
SIN,26/UPONLINE,1,1,D,I*
DEF,1"SUBNETWORK FOR SCM #1        TAC SOURCE NODE
SOU,5, ,1,(50)10*
VAS,5, ,UF,1,(50)20*
ACT,5, ,EX,1,(50)30*
```

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```
ACT,5,5,,(5)14**
REG,5,5,,1,(50)50*
ACT,5,,,(5)50**
QUE,7/INPUTBUF,(6)S/2,(50)70* SCM INPUT QUEUE
ACT,7,,,US,1,7/PROCESSOR,(50)80*
REG,8,,,1,F,(50)90*
ACT,8,,UF,101,(8)1,45,LT,-,10,(50)100*
ACT,9,,0,(8)2,A6,LE,0,6,(50)110* LOCAL DELIVERY
ACT,9,,1,(8)3,A5,LE,1,,(50)120* LINE 1
ACT,9,,2,(8)4,A5,LE,2,,(50)130* LINE 2
ACT,3,,3,(8)5,A6,LE,3,,(50)140* LINE 3
ACT,8,,4,(8)5,A5,LE,4,,(50)150* LINE 4
ACT,8,,5,(8)7,A5,LE,5,,(50)160* LINE 5
REG,9,,1,(50)170*              MAY GO TO NODE 5 OR 8 OF ANY SCM
ACT,9,21,(50)18**
SIN,24/DISCARD,1,1,D,I,(50)190*
SIN,1*/LOCALDELIVERY,1,1,D,I,(50)200*
QUE,11/OUTBUFF 1,(5)S/2,(50)210* OUTPUT BUFFER FOR LINE 1
ACT,11,16,UF,1 (2,(50)220*
REG,15,1,1,(50)230*
QUE,12/OUTBUFF 2,(5)S/2,(50)240* OUTPUT BUFFER FOR LINE 2
ACT,12,17,UF,1,2,(50)250*
REG,17,1,1,(50)260*
QUE,13/OUTBUFF3,(5)S/2,(50)270* OUTPUT BUFFER FOR LINE 3
ACT,13,18,UF,1,2,(50)280*
REG,13,1,1,(50)290*
QUE,14/OUTBUFF4,(5)S/2,(50)390* OUTPUT BUFFER FOR LINE 5
ACT,14 19,UF,1 (2,(50)310*
REG,19,1,1,(50)320*
QUE,15/OUTBUFF 5,(5)S/2,(50)330* OUTBUFFER FOR LINE 4
ACT,15,20,UF,1,2,(50)340*
REG,2* 1,1,(50)350*
ESN*
DUB,2**
REP,20,VAS,5,1,UF,2*
REP,30,ACT,5,5,EX,2*
REP,8*,ACT,7,8,US,2*
```

SUBNETWORK FOR SCM 2

SUBNETWORK FOR SCM 3

SUBNETWORK FOR SCM 4

SUBNETWORK FOR SCM 7

SUBNETWORK FOR SCM 8

SUBNETWORK FOR SCM 9

SUBNETWORK FOR SCM 10

```
110417
110427
110437
110448
110457
110469
110477
110483
110497
110509
110515
110527
110537
110549
110356
110569
110578
110589
110599
110509
110610
110629
110639
110649
110659
110569
110679
110689
110699
110709
110719
110729
110-33
110747
110759
110769
110773
```

```
ESN*
DUP,3,5*
REP,20,VAS,5,1,UF,3*
REP,30,ACT,5,5,EX,3*
REP,80,ACT,7,8,US,3*
ESN*
DUP,4,5*
REP,20,VAS,5,1,UF,4*
REP,30,ACT,5,5,EX,4*
REP,80,ACT,7,8,US,4*
ESN*
DUP,5,5*
REP,20,VAS,5,1,UF,5*
REP,30,ACT,5,5,EX,5*
REP,80,ACT,7,8,US,5*
ESN*
DUP,6,5*
REP,20,VAS,5,1,UF,6*
REP,30,ACT,5,5,EX,6*
REP,80,ACT,7,8,US,6*
ESN*
DUP,7,5*
REP,20,VAS,5,1,UF,7*
REP,30,ACT,5,5,EX,7*
REP,80,ACT,7,8,US,7*
ESN*
DUP,8,5*
REP,20,VAS,5,1,UF,8*
REP,30,ACT,5,5,EX,8*
REP,80,ACT,7,8,US,8*
ESN*
DUP,9,5*
REP,20,VAS,5,1,UF,9*
REP,30,ACT,5,5,EX,9*
REP,90,ACT,7,8,US,9*
ESN*
DUP,10,5*
```

```
REP,2C,VAS,5,1,UF,10*        SUBNETWORK FOR SCM 11        110787
REP,3C,ACT,5,5,EX,10*                                     110797
REP,8C,ACT,7,8,US,10*                                     110807
ESN*                                                      110817
DUP,11,E*                                                 110827
REP,2C,VAS,5,1,UF,11*        SUBNETWORK FOR SCM 12        110837
REP,3C,ACT,5,5,EX,11*                                     110847
REP,8C,ACT,7,8,US,11*                                     110857
ESN*                                                      110867
DUP,12,E*                                                 110877
REP,2C,VAS,5,1,UF,12*        SUBNETWORK FOR SCM 13        110887
REP,3C,ACT,5,5,EX,12*                                     110897
REP,8C,ACT,7,8,US,12*                                     110907
ESN*                                                      110917
DUP,13,E*                                                 110927
REP,2C,VAS,5,1,UF,13*        SUBNETWORK FOR SCM 14        110937
REP,3C,ACT,5,5,EX,13*                                     110947
REP,8C,ACT,7,8,US,13*                                     110957
ESN*                                                      110967
DUP,14,E*                                                 110977
REP,2C,VAS,5,1,UF,14*        SUBNETWORK FOR SCM 15        110987
REP,3C,ACT,5,5,EX,14*                                     110997
REP,8C,ACT,7,8,US,14*                                     111007
ESN*                                                      111017
DUP,15,E*                                                 111027
REP,2C,VAS,5,1,UF,15*        SUBNETWORK FOR SCM 16        111037
REP,3C,ACT,5,5,EX,15*                                     111047
REP,8C,ACT,7,8,US,15*                                     111057
ESN*                                                      111067
DUP,16,E*                                                 111077
REP,2C,VAS,5,1,UF,16*                                     111087
REP,3C,ACT,5,5,EX,16*                                     111097
REP,8C,ACT,7,8,US,16*                                     111107
ESN*                                                      111117
FIN*                                                      111127

1 1 2     R,C7,3813 E 6        2182. 645. 545.   0.   3.051.93   001
1 1                                      .14  .22  .32 .C7.C6.04.09.36  002
```

```
10 5     7
11 6 2      8.14.47 814
11 6       7       7      2423.1557.      7       7     0..01.93
11 6             .06    .14    .24     .05.05.33.16.22
11 6             .50    .50    .56     .50.50.51.50.56
12 5 2      8.14.47 61513
12 5             9
12 5       7       7      2423.1657. 379.      7     0..01.93
12 5             .06    .14     .06.05.33.16.22
12 5             .50    .56     .50.50.56.50.50
13 7 1      19.38.24 1 2 812
13 7             9
13 7       7       7     2142.2132.2244. 373.      7     0..01.93
13 7             .15    .25    .71     .37.11.16.12.13
13 7             1.0    1.0    1.0     1.01.01.71.01.0
14 8       7
14 8 2      17.05.2711 8 5
14 8             7       7     1657. 906.1298.   0.      7     0..01.93
14 8             .14    .13    .12     .14.08.14.07.28
14 8             .33    .33    .33     .33.33.33.33.33
15 8 3      17.05.2712 6 3
15 8             7       7     1657.1298.1298.   0.      7     0..01.93
15 8             .14    .13    .02     .14.08.14.07.28
15 8             .33    .33    .33     .33.33.33.33.33
16 8 3      17.05.27 9 4 2
16 8             7       7      905.1298. 539.   0.      7     0..01.99
16 8             .14    .13    .12     .14.08.16.07.28
16 8             .34    .34    .34     .34.34.34.34.34
15 3    .21.01       5
7/8/9 28 4502      17.0 5030      17.0 5030      1.0

PROGRAM STRIP(OUTPUT,TAPE1,TAPE5=OUTPUT,TAPE2)
HIS PROGRAM STRIPS ALL TRACE DATA RECORDS FROM QSERT
OUTPUT AND (1) PRINTS THE REMAINING QSERT OUTPUT AND (2),
ELECTS DATA RECORDS 5, 15 AND 16 THRU 21 NODE NUMBERS
TO PROVIDE DATA FOR TRACKING IN THE NETWORK.
NTEGER CONE
DIMENSION LINE(27),NODE(9)
ATA NODE/"  8-","  10-","  15-","  17-","   18-",
X"  19-","  20-","  21-","NODES"/
DONE=0,  QSERT DATA TO **TRACE**
```

```
C   DONE=1,  TRACE DATA TO QGERT SIMULATION
C   DONE=2,  QGERT DATA TO END OF FILE
C   N=0
   11 READ(1,90)(LINF(I),I=1,22)
   30 FORMAT(2A10,A5,A2,2(A3,A9),2A10,A3,A5,5(A3,A7))
      IF(EOF(1).NE.0)GO TO 100
      IF((LINE 16).EQ." +++").AND.(LINE(7).EQ."TRA"))GO TO 20
      WRITE(5,50)(LINE(I),I=1,22)
      GO TO 11
   20 READ(1,90)(LINE(I),I=1,22)
      IF(EOF(1).NE.0)GO TO 100
C   SELECT PACKET NODE = 8, 10 AND 16 - 21
C   WRITE PACKET DATA TO TAPE2
      IF(LINE(8).EQ." ")GO TO 22
      DO 40 I=1,9
   40 IF(LINE(3).EQ.NODE(I))GO TO 50
      IF(LINE(2).EQ."ZZZZZZZZZZZ") GO TO 10
      GO TO 20
   50 READ(1,90)(LINE(I),I=23,27)
      IF(EOF(1).NE.0)GO TO 100
   31 FORMAT(8 1X,5(3X,A7))
      WRITE(2,32)LINE(3),(LINE(2*I),I=2,11),(LINE(I),I=23,27)
   32 FORMAT(A 6,A2,2A9,A10,A6,10A7)
      GO TO 20
  100 CONTINUE
      STOP
      END
7/8/3 OR *EOR
SORT
FILE,TAPUT=TAPE2(CR),OUTPUT=TAPE3(CR)
FIELD,SRT3(1,5,DISPLAV),SRT2(10,9,DISPLAY),SRT1(27,16,DISPLAY)
KEY,SD-1(A,COROLE),SRT2(A,COROLE),SFT3(A,COROLE)
END
7/8/3 OR *EOR
PROGRAM SUMARI7(TAPE4,TAPE5,OUTPUT,TAPE6=OUTPUT,TAPE3)
IMENSION NODESCM(8,5),ATT(10),DATA(5,2),PROCTIM(25,3,2)
X,PERCENT(3)
```

B-35

```
      REAL MARKTIM
      INTEGER TNODE,SCM,SCMNODE(25)
C     THIS PROGRAM SUMMARIZES THE SORTED PACKET DATA OF THE AUTODIN II
C     NETWORK IN TAPE3 TO A SINGLE RECORD ON TAPE4 FOR ANALYSIS.
      DO 5 I=1,25
5     SCMNODE(I)=0
      DO 10 L=1,25
      DO 10 I=1,3
      DO 10 J=1,2
10    PROCTIM(L,I,J)=0.0
C     THE FIRST 8 DATA CARDS MUST BUILD THE NODE-SCM ARRAY
      DO 120 Y=1,8
      READ(3,300)ITRANS,(ATT(L),L=1,10)
      IF(EOF(3).NE.0)GO TO 400
300   FORMAT(36X,I5,1X,10F7.0)
      IF(ITRANS.EQ.1)GO TO 100
      WRITE(5,310)
310   FORMAT(" 900 CARDS MISSING - NO NODE TO SCM ARRAY POSSIBLE",//
     X" PROCESSING STOPPED IN SUMARIZ")
      STOP
100   DO 110 J=1,5
      IF(IFIX(ATT(J)).LE.25.0)SCMNODE(IFIX(ATT(J)))=I
110   CODESCM(I,J)=IFIX(ATT(J))
      WRITE(5,920)I,(NODESCM(I,J),J=1,5)
920   FORMAT(" NODE",I2," CONTAINS THE FOLLOWING SCMS?",5I8)
120   CONTINUE
C     BEGIN SUMMARIZING THE SORTED PACKET DATA FOR A COMPLETE TRANSACTION
C     NUMBER INTO A SINGLE RECORD
200   READ(3,315)NODE,TIMEIN,TIMEOUT,MARKTIM,ITRANS,(ATT(I),I=1,10)
      IF(EOF(3).NE.0)GO TO 400
315   FORMAT(I5,3X,2F9.2,F10.2,I5,1X,10F7.2)
      DO 210 I=1,8
      DO 210 J=1,2
210   DATA(I,J)=0.0
      IOP=0
C     CHECK IF FIRST NODE RECORD ENTERING AN SCM IS AN 8 (FOR NODE 8)
      IF(NODE.NE.8)225,226
```

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```
C     CHECK IF THIS IS A STATUS PACKET
225   IERR=1
      IF((HOP.NE.0).AND.(IFIX(ATT(1)).NE.1))GO TO 230
      ICM=ATT(8)
      INODE=SC MNODE(SCM)
C     COMPUTE PROCESSOR TIME IN ATT??????
      PROCTIM(SCM,1,1)=PROCTIM(SCM,1,1)+ATT(7)
      PROCTIM(SCM,1,2)=PROCTIM(SCM,1,2)+1.0
      TIME=MARKTIM+ATT(7)
      GO TO 235
226   CONTINUE
      IF(HOP.EQ.0)TIME=MARKTIM
C     COMPUTE INPUT QUEUE TIME (NODE 7)
      ICM=ATT(8)
      INODE=SC MNODE(SCM)
C     COMPUTE PROCESSING TIME
      PROCTIM(SCM,IFIX(ATT(1)),1)=PROCTIM(SCM,IFIX(ATT(1)),1)+
     X TIMEOUT-TIMEIN
      PROCTIM(SCM,IFIX(ATT(1)),2)=PROCTIM(SCM,IFIX(ATT(1)),2)+1.0
      TIME=TIMEOUT
231   DATA(TNODE,1)=TIMEIN-TIME
      TIME=TIMEOUT
C     IS THIS PACKET TO BE TRANSMITTED TO ANOTHER NODE
      READ(3,215)NODE,TIMEIN,TIMEOUT,MARKTI4,ITRANS,(ATT(I),I=1,12)
      IF(EOF(3).NE.0)GO TO 400
C     COMPUTE OUTPUT QUEUE TIME AND TRANSMISSION TIME
235   IF((NODE.LT.15).OR.(NODE.GT.20))GO TO 240
      DATA(TNODE,2)=TIMEIN-TIME
      DATA(TNODE,3)=TIMEOUT-TIMEIN
      TIME=TIMEOUT
      HOP=HOP+1
C     COMPUTE HOP SEQUENCE NUMBER
      DATA(TNODE,4)=HOP
      TRANS=ITRANS
      READ(3,215)NODE,TIMEIN,TIMEOUT,MARKTI4,ITRANS,(ATT(I),I=1,12)
      IF(EOF(3).NE.0)GO TO 400
C     IS THIS THE SAME PACKET
      IERR=2
```

```
265   IF(ITRANS.EQ.LTRANS)220,370
266   CONTINUE
C     THIS PACKET GOING TO BE DELIVERED/DISCARDED - NODE=10 OR 21
      IF((NODE.NE.21).AND.(NODE.NE.10))GO TO 305
C     COMPUTE TOTAL TIME PACKET IN SYSTEM
      TIME=TIMEOUT-MARKTIM
C     OUTPUT QUEUE TIME AND TRANSMISSION TIME ARE ZERO
      DATA(TNODE,2)=0.0
      DATA(TNODE,3)=0.0
      DATA(TNODE,4)=HOP+1
      IF((NODE.EQ.21).AND.(ATT(1).GE.2.0))HOP=-10.-HOP
      WRITE(5,934)MARKTIM,(ATT(I),I=1,4),ATT(10),HOP,TTIME
934   FORMAT("  ",F9.2,6F4.3,F10.2)
      WRITE(4,935)MARKTIM,(ATT(I),I=1,4),ATT(10),HOP,TTIME,((DATA(I,J),
     X J=1,4),I=1,8)
935   FORMAT(F10.2,6F4.,F10.2,4(/2(3F10.2,F4.0)))
      GO TO 220
C     CONVERT SOURCE AND DESTINATION SCHS TO NODES
370   ATT(3)=SCMNODE(IFIX(ATT(3)))
      ATT(4)=SCMNODE(IFIX(ATT(4)))
      WRITE(5,915)NODE,TIMEIN,TIMEOUT,MARKTIM,ITRANS,(ATT(I),I=1,10)
C     ASSIGN IERR=2 IF PACKET DOES NOT PROCESS THRU THE NETWORK
C     IERR=1 IF PACKET IS MISSING A BEGIN NODE 8 (NOT STATUS PACKET)
      WRITE(5,936)IERR
936   FORMAT("  ABOVE RECORD, ERROR CODE ",I3//)
      IF(IERR.EQ.1)200,205
205   CONTINUE
C     WRITE OUT PROCESSOR TIME INFORMATION
      DO 430 I=1,25
      IF(SCMNODE(I).EQ.0)STOP
      WRITE(5,940)
940   FORMAT(1X," PROCESSOR TIME UTILIZATION SCM =",I8,
     X //21X," QUANTITY   PROCESSOR   PROCESSOR",
     X /21X," OF PACKETS   TIME",/)
      DO 410 J=1,3
      PERCENT(J)=0.0
410   IF(PROCTIM(I,J,2).GE.1.0)PERCENT(J)=100.*PROCTIM(I,J,1)/TIME
```

```
350 WRITE(5,950)((PROCTIM(I,J,2),PROCTIM(I,J,1),PERCENT(J)),J=1,3)
950 FORMAT(5X," STATUS PACKETS   ",F7.0,3X,F9.2,4X,F5.2,
    X/5X," SHORT PACKETS   ",F7.0,3X,F9.2,4X,F5.2,
    X/5X," LONG PACKETS    ",F7.0,3X,F9.2,4X,F5.2,//)
    SUM1=0.0
    SUM2=0.0
    PRCNT=0.0
    DO 420 J=1,3
    SUM1=SUM1+PROCTIM(I,J,1)
420 SUM2=SUM2+PROCTIM(I,J,2)
    PRCNT=SUM1/TIMF
    WRITE(5,960)SUM1,SUM2,PRCNT,TIMF
960 FORMAT(5)," TOTAL",11X,F7.0,3X,F9.2,4X,F5.2)
350 CONTINUE
430 CONTINUE
    STOP
    END

7/9/3 JR *EOR
RUN NAME       FORT DIETRICK DOWN
VARIABLE LIST  TIME,ATT1 TO ATT4,SYS,HOP,TTIME,XC1 TO X32
INPUT FORMAT   FIXED(F10.2,6F4.0,F10.2/2(3F10.2,F4.0)/2(3F10.2,F4.0)/
               2(3F10.2,F4.0)/2(3F10.2,F4.0))
INPUT MEDIAN   DISK
VAR LABELS     TIME,MARKTIME/ATT1,TYPE OF PACKET/ATT2,PRIORITY/
               ATT3,SOURCE NODE/ATT4,DESTINATION NODE/
               SYS,TYPE OF WORKLOAD/HOP,NUMBER OF HOPS/
               TTIME,TOTAL TIME IN NETWORK/
               XC1,NODE 1 INPUT QUEUE/X02,NODE 1 OUTPUT QUEUE/
               XC3,NODE 1 TRANSMISSION TIME/X04,NODE 1 HOP SEQUENCE/
               XC5,NODE 2 INPUT QUEUE/X06,NODE 2 OUTPUT QUEUE/
               X07,NODE 2 TRANSMISSION TIME/X08,NODE 2 HOP SEQUENCE/
               XC9,NODE 3 INPUT QUEUE/X10,NODE 3 OUTPUT QUEUE/
               X11,NODE 3 TRANSMISSION TIME/X12,NODE 3 HOP SEQUENCE/
               X13,NODE 4 INPUT QUEUE/X14,NODE 4 OUTPUT QUEUE/
               X15,NODE 4 TRANSMISSION TIME/X16,NODE 4 HOP SEQUENCE/
               X17,NODE 5 INPUT QUEUE/X18,NODE 5 OUTPUT QUEUE/
               X19,NODE 5 TRANSMISSION TIME/X20,NODE 5 HOP SEQUENCE/
               X21,NODE 5 INPUT QUEUE/X22,NODE 6 OUTPUT QUEUE/
```

```
VALUE LABELS  X23,NODE 5 TRANSMISSION TIME/X24,NODE 6 HOP SEQUENCE/
              Y25,NODE 7 INPUT QUEUE/X25,NODE 7 OUTPUT QUEUE/
              Y27,NODE 7 TRANSMISSION TIME/X28,NODE 7 HOP SEQUENCE/
              X29,NODE 8 INPUT QUEUE/X30,NODE 8 OUTPUT QUEUE/
              X31,NODE 8 TRANSMISSION TIME/X32,NODE 8 HOP SEQUENCE/
              ATT1(1)STATUS PACKET(2)SHORT PACKET(3)LONG PACKET/
              ATT2(5)NETWORK PRIORITY(10)CAT I(20)CAT II(30)CAT III
              (40)CAT IV/ATT3 TO ATT4(1)ALBANY(2)ANDREWS(3)FT. DETRICK
              (6)GENTILE(5)HANCOCK(5)MCCLE-LAN(7)NORTON(8)TINKER

SELECT IF       (TIME GE 1000 AND TIME LT 10000 AND HOP GE 0)
CONDESCRIPTIVE  HOP,TTIME
*COMPUTE        TIME=250.*TRUNC(TIME/250.)
BREAKDOWN       TABLES=TTIME BY TIME BY ATT2 BY ATT1/
                TTIME BY ATT2

*COMPUTE        TIME=100.*TRUNC(TIME/100.)
BREAKDOWN       TABLES=TTIME BY TIME BY ATT2/
                TTIME BY TIME BY ATT2 BY ATT1/
                TTIME BY HOP BY ATT1/
                TTIME BY HOP/
                TTIME BY TIME BY HOP

*SELECT IF      (X04 GT 0)
CONDESCRIPTIVE  X01 TO X03
*SELECT IF      (X08 GT 0)
CONDESCRIPTIVE  X05 TO X07
*SELECT IF      (X12 GT 0)
CONDESCRIPTIVE  X09 TO X11
*SELECT IF      (X16 GT 0)
CONDESCRIPTIVE  X13 TO X15
*SELECT IF      (X20 GT 0)
CONDESCRIPTIVE  X17 TO X19
*SELECT IF      (X24 GT 0)
CONDESCRIPTIVE  X21 TO X23
*SELECT IF      (X28 GT 0)
CONDESCRIPTIVE  X25 TO X27.
*SELECT IF      (X32 GT 0)
CONDESCRIPTIVE  X29 TO X31
*SELECT IF      (ATT1 EQ 2)
```

```
COMPUTE  PERCNT=1
IF       (TIME GE 2.00)PERCNT=2
IF       (TIME GE 3.00)PERCNT=3
COMPUTE  TRAF=3
IF       (TIME GE 2.00)TRAF=2
IF       (TIME GE 3.00)TRAF=3
COMPUTE  PRI=1
IF       (ATT2 EQ 10)PRI=2
IF       (ATT2 EQ 20)PRI=3
IF       (ATT2 EQ 30)PRI=4
IF       (ATT2 EQ 40)PRI=5
ANOVB    TTIME BY PERCNT(1,3)/
         TTIME BY PERCNT(1,3),PRI(1,5)/
         TTIME BY PERCNT(1,3),PRI(1,5),TRAF(1,3)/
SELECT IF (ATT1 GE 2)
COMPUTE  PERCNT=1
IF       (TIME GE 20.00)PERCNT=2
IF       (TIME GE 30.00)PERCNT=3
IF       (TIME GE 40.00)PERCNT=1
IF       (TIME GE 50.00)PERCNT=2
IF       (TIME GE 60.00)PERCNT=3
IF       (TIME GE 70.00)PERCNT=1
IF       (TIME GE 80.00)PERCNT=2
IF       (TIME GE 90.00)PERCNT=3
COMPUTE  TRAF=1
IF       (TIME GE 45.00)TRAF=2
IF       (TIME GE 70.00)TRAF=3
COMPUTE  PRI=1
IF       (ATT2 EQ 10)PRI=2
IF       (ATT2 EQ 20)PRI=3
IF       (ATT2 EQ 30)PRI=4
IF       (ATT2 EQ 40)PRI=5
ANOVA    TTIME BY PERCNT(1,3)/
         TTIME BY PERCNT(1,3),TRAF(1,3)/
         TTIME BY PERCNT(1,3),PRI(1,5)/
COMPUTE  TIME=100.*TRUNC(TIME/100.)
SELECT IF (HOP GE 2)
```

```
BREAKDOWN    TABLES=TTIME BY TIME BY HOP/
             TTIME BY TIME BY HOP BY ATT1

*SELECT IF   (TIME GE 2030)
*COMPUTE     TIME=1000.*TRUNC(TIME/1000.)
BREAKDOWN    TABLES=TTIME BY TIME BY ATT1/
             TTIME BY HOP BY ATT1/
             TTIME BY HOP

*SELECT IF   (SYS GE 2)
*COMPUTE     TIME=1000.*TRUNC(TIME/1000.)
BREAKDOWN    TABLES=TTIME BY TIME BY ATT2 BY ATT1/
             TTIME BY HOP BY ATT2 BY ATT1/
             TTIME BY TIME BY HOP/
             TTIME BY ATT2 BY ATT1

*SELECT IF   (ATT3 EQ 15)
*COMPUTE     TTIME=1000.*TRUNC(TIME/1000.)
BREAKDOWN    TABLES=TTIME BY ATT2 BY ATT1/
             TTIME BY HOP BY ATT2 BY ATT1

*SELECT IF   (ATT3 EQ 15)
T-TEST       GROUPS=TIME(5000)/VARIABLES=TTIME
*SELECT IF   (HOP GE 2)
T-TEST       GROUPS=TIME(5000)/VARIABLES=TTIME
FINISH
```

VITA

James W. Healy was born ▉▉▉▉▉▉▉▉▉▉▉▉
▉▉▉▉▉▉▉▉▉▉▉▉▉▉▉ He graduated from ▉▉▉▉▉▉▉▉▉▉▉▉

▉▉▉▉▉▉▉▉ in 1958. He later attended Brigham Young
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19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*
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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*
This thesis report presents a discussion of the AUTODIN II system, describes a simulation of the AUTODIN II backbone network and presents an analysis of two aspects of the AUTODIN II system. A general overview of the AUTODIN II topology and architecture is presented. A detailed discussion of the present state of the AUTODIN II routing algorithm, it's function, modules and information structures is presented. A discrete packet simulation is developed with dynamic capabilities to redefine the network configuration or workload. The

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simulation program inputs and outputs are described to provide future AUTODIN II system analysts the capability of defining their particular requirements. A users manual is also developed. A presentation of the analyses and results of opposite views is given; (1) from the system designer's view of overall AUTODIN II capability and (2) from the user's view of what the effects will be for a specific AUTODIN II user. The use of the simulation model by other organizations for analysing management problems and concerns is encouraged.